National Park Service
U.S. Department of the Interior

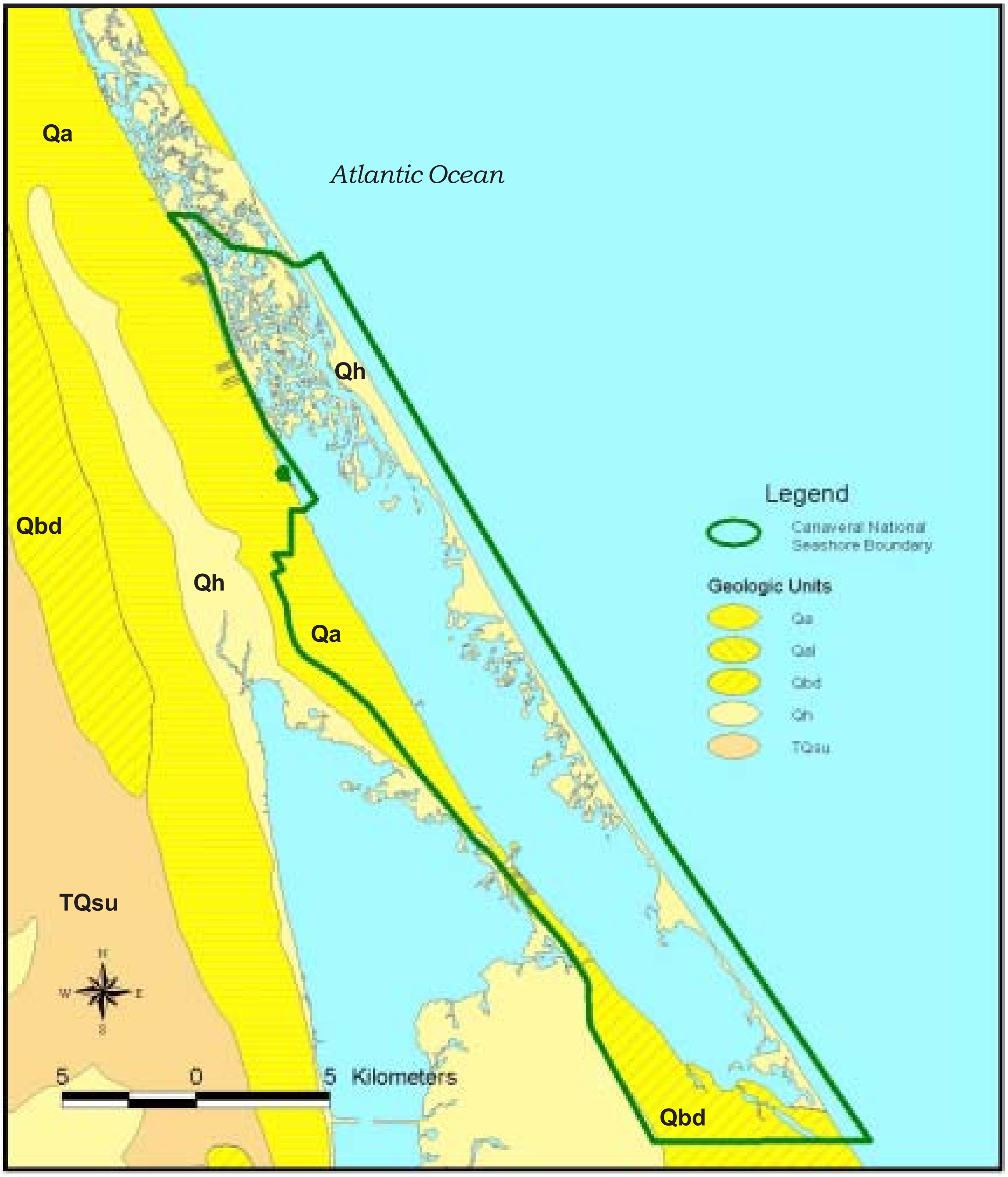
Geologic Resources Division
Geological Resources Inventory

# Coastal Geology Mapping Protocols for the Atlantic and Gulf National Park Units

## Canaveral National Seashore and Titusville, Florida

## June 25-27, 2002

## NPS-D-2269



U.S. Department of Interior
Gale A. Norton, Secretary

National Park Service
Fran Mainella, Director

# GEOLOGIC RESOURCES INVENTORY

*Coastal Mapping Protocols Workshop for Atlantic and Gulf National Parks*

Canaveral National Seashore • Titusville, Florida
June 25-27, 2002

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For additional materials from the *Mapping Protocols Workshop*, including notebook contents, MS power point presentations, and Coastal Park fact sheets, please visit www.nature.nps.gov/grd/geology/gri/coastal.

## EXECUTIVE SUMMARY

A comprehensive geologic resource inventory and mapping program is necessary for the effective management of our coastal national parks. At present, the National Park Service (NPS) recognizes 97 coastal units that encompass more than 7,300 miles of shoreline. In coastal areas, surficial and subsurface geology are complexly intertwined with park flora, fauna, water, air, and cultural resources. In addition, relative sea-level rise, geologic hazards, and anthropogenic modifications create an immediate need for detailed geologic mapping in coastal areas. *Presently, no mapping products or standards exist to meet this need.* The Geologic Resources Inventory (GRI), cooperatively administered by the NPS Inventory and Monitoring Program and the NPS Geologic Resources Division, took an important first step in meeting the geologic and surficial landform mapping requirements of NPS coastal park units.

The GRI coordinated and funded a Coastal Mapping Protocols workshop on June 25-27, 2002 at Canaveral National Seashore (CANA) to address coastal park mapping needs and coastal management issues. This workshop brought together 38 federal, state, academic, and private industry employees including park managers, coastal geologists, resource specialists, information technology specialists and inventory & monitoring coordinators, to establish coastal mapping protocols for Atlantic and Gulf coastal parks in the National Park Service. Workshop participants discussed coastal park management issues and formulated a draft list of Coastal Landform Mapping (CLM) units that should be incorporated into coastal geology mapping products. GRI staff members will integrate the identified coastal mapping units into the NPS Geology-GIS Data Model, the documented standard for digital geologic maps within the NPS.

Building upon this list of mapping units, an inventory of the significant geologic resources contained within each coastal unit will be identified during GRI scoping meetings. In addition, scoping meetings will determine individual park mapping priorities and needs. The GRI will attempt to provide coastal National Park units with bedrock geology, surficial geology and/or landform mapping products. Mapping products should include GIS digital coverages, hard copy geologic maps, and/or supplemental information regarding significant geologic features and processes found within each park unit. When possible, the GRI may also supply coastal parks with existing bathymetric, topographic, and benthic habitat mapping coverage. These maps will provide the geologic framework and base cartographic information necessary for park managers to effectively monitor coastal change and shoreline dynamics. GRI coordinators have outlined several inventory action items and more specific project tasks related to CLM that will be included in the FY2003 GRI work plan (Appendix 8).

The participants of the Coastal Mapping Protocols Workshop strongly encouraged a "holistic" ecosystem approach for the effective management of our federally protected coastal parks. To understand the broad range of multi-faceted issues commonly confronting coastal park managers, coastal landform maps should be integrated with biological and physical system components, including vegetation, species habitat, and oceanographic variables. Park infrastructure, boundary information, shoreline engineering, and cultural resources may also be integrated with the final geologic map products. GRI staff members will work with coordinators of other Natural Resource inventories and their partners to identify and initiate possible integrated data collection and mapping projects. Cooperative projects may allow significant cost savings for the inventories and higher quality data products for park managers. These additional mapping components will increase understanding of complex coastal environments, allowing park managers to make better-informed and more effective management decisions.

## DEDICATION

This report is dedicated to the late DR. JAMES R. ALLEN, a coastal geomorphologist in the U.S. Geological Survey and U.S. National Park Service. Jim was an active participant in the Coastal Mapping Protocols meeting and also conducted beach surveys at Canaveral National Seashore the days prior to and following this workshop. His input, insight, and passionate disposition will be missed.

Jim died on July 30, 2002. He often said that he had the best job in the world, being paid to be on beaches throughout the coastal national parks. Jim received his Ph.D. at Rutgers University in the early 1970s where he was supervised by Norbert Psuty. Early in his career, Jim taught at Northeastern University in Boston and at the University of Arkansas. In 1981 Jim returned to Boston, to serve as a coastal geomorphologist for the Northwest Region of the National Park Service. Later his unit was transferred to the USGS.

Jim was an avid empirical researcher. He delighted in being in the field and deploying equipment to conduct measurements and build data records. Jim could often be found in the field beside an array of current meters, pressure transducers, laser surveying gear, reels of cable, data loggers, and a portable generator to power the mix of equipment. Once back in the lab, Jim would download the data and analyze a wide variety of measurements. His publications and reports are data-rich and based on well-conceived study. He provided us with knowledge of the physical functions of coastal systems within the parks through publications, professional presentations, and internal reports.

Jim applied coastal science to coastal management concerns, including resource management and decision-making. He valued the beaches and dunes in the parks and used his scientific acumen to help guide the parks in their stewardship of these vital national resources. Through his knowledge of geomorphic mapping and dynamic sedimentary environments, Jim was able to guide resource management decisions by discussing the important scales of variability for each park. The maintenance of naturally functioning ecosystems was facilitated by lengthy and numerous discussions with park staff that led to a better-educated core of park administrators. Jim's fieldwork extended from Acadia National Park in Maine to Padre Island National Seashore in Texas. Most recently, Jim was active in developing a shoreline monitoring program for the Northeast coastal parks, using knowledge gained from many years of research in Cape Cod National Seashore, Gateway National Recreation Area, and Fire Island National Seashore. He was among the first coastal scientists to begin using dynamic-GPS equipment to record and track shoreline changes, and he built a historical database in the parks that is setting the standard for GIS applications in the coastal parks.

Jim was active in the disciplines of geography and geology. He held an office in a disciplinary coastal specialty group and regularly presented at national and international meetings. Most uniquely, Jim was able to simultaneously communicate his love of coastal sediment dynamics to the park ranger, park superintendent, and university colleague on the same site visit. His enthusiasm was unparalleled. His cadre of friends and fellow geomorphologists was spread around the world. He will be missed by all of us who knew him as a friend and a colleague.

Rebecca Beavers, Ph.D.
National Park Service, Coastal Geomorphologist
September 2002

## ACKNOWLEDGEMENTS

We would like to gratefully acknowledge the employees of Canaveral National Seashore for aiding in workshop planning and coordination, and for allowing participant use of park resources for educational and recreational purposes. Special thanks to Bob Newkirk (Superintendent), John Stiner (Chief of Natural Resources) and Donald Mock (Geologist) for the use of the Eldora House and the "turtle watch" tour. In addition, many thanks to Randy Parkinson, of the Coastal Technology Corporation, for conducting a very informative field trip through Canaveral National Seashore.

## COVER PAGE CREDITS

Geologic map of Florida highlighting Canaveral National Seashore park boundaries. This map illustrates that a surficial geologic map of coastal parks is not sufficient for solving complex coastal management issues. The homogenous geologic divisions do not adequately portray dynamic coastal environments and geological variability.

Data sources: Florida Geologic Survey and National Park Service (park boundary layer)
Cover design: Matt Schaefer, GIS Technician, NPS Geologic Resource Division.

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## INTRODUCTION

The NPS Geologic Resources Inventory Program (GRI) hosted a Coastal Mapping Protocols Workshop for Atlantic and Gulf National Park Units on June 25-27, 2002 at Canaveral National Seashore. Workshop participants included coastal geologists, park managers, natural resource specialists, information technology consultants, and inventory and monitoring coordinators (Appendix 2). The purpose of this workshop was to establish GRI mapping protocols for National Parks along the Atlantic and Gulf coasts.

Workshop participants discussed coastal geologic mapping needs and formulated a list of specific mapping units for coastal parks. The major coastal map units chosen include Anthropogenic, Supratidal, Intertidal, Subtidal, and Coastal-Riverine features. This list of coastal map units will be revised as park-specific needs are identified during future individual coastal park GRI Scoping meetings. GRI staff will integrate the identified coastal mapping units into the NPS Geology-GIS Data Model, the documented standard for digital geologic maps within the NPS.

Extremely complex features and processes characterize coastal environments. Workshop participants strongly recommended that biological and physical components should be integrated into coastal mapping products. These mapping units are related to landforms and include, but are not limited to, basic vegetation classes, identifiable species habitat, and geomorphic and oceanographic variables. In addition, mappable surface features such as cultural resources, park infrastructure and anthropogenic modifications may be integrated into coastal area maps for improved coastal zone monitoring and management.

Through interagency partnerships, including but not limited to, the United States Geological Survey (USGS), National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA), state, academic, and private industry, the GRI will provide vital mapping products to coastal national parks as part of a comprehensive geologic resources inventory identified by the NPS Inventory and Monitoring Program. The GRI will provide each park with 1) a park specific bibliography of geologic literature and maps; 2) on-site evaluations of park geologic maps, resources, and issues; 3) a summary report with basic information on the park's geology, geologic hazards, issues, and existing data and studies; and 4) digital geologic mapping products with accompanying supporting information. The final mapping products will provide a baseline to aid in the understanding of geologic processes affecting coastal health and sustainability and in implementing an effective ecological monitoring program.

This report summarizes workshop proceedings and presents the final draft of coastal geology mapping units that will be utilized for mapping coastal landforms and features in Atlantic and Gulf coastal parks. In addition, this report may be used to assist coastal park managers to understand geologic mapping procedures. We have included a Federal contact list (Appendix 1), geologic resource inventory status (Appendix 7), and a coastal mapping unit checklist (p.20) to assist during future park-specific GRI scoping meetings.

## COASTAL PARK MANAGERS AND GEOLOGIC RESOURCE MANAGEMENT

Many NPS coastal parks have a small number of employees who are required to fulfill a variety of functions including, but not limited to, administration, fire management, interpretive guidance, maintenance, law enforcement and public relations. In addition to these collateral duties, park managers (many with limited scientific backgrounds) are charged with the preservation and protection of coastal geologic resources within their care. It is critical that park managers are provided with the assistance necessary to make informed coastal management decisions.

A detailed inventory of coastal geologic features and processes should be compiled within each coastal park. This process will require interagency, university, and private sector partnerships, and close communication among GRI and park staff, regional coordinators, and NPS coastal geology specialists. Also, the Geologic Resources Division, GRI staff, and other Natural Resource Program Center divisions will provide direct technical assistance to park staff for inventory and mapping needs. Coastal park managers should initiate and maintain communications and partnerships that will allow the pooling of resources, funding, and scientific expertise. In addition, GRI staff will host a geologic resource workshop for each park unit. These meetings are designed to assess the significant geologic resources and management needs of each coastal park

Upon completion of a geologic resource inventory, it is vital that coastal park managers can access and interpret produced data to assist in coastal management decisions. Digital map layers will contain descriptive legends and associated graphics via clickable mapping units in ArcView GIS. This feature will provide readily accessible supplemental information on each geologic feature identified. In addition, the GRI and the NPS coastal geology staff will provide technical support and map interpretation guidance when requested. The NPS Inventory and Monitoring Program will provide data management assistance and training, and the NPS GIS Program (Information Technology Center) can provide additional information concerning GIS resources including GIS training workshops. Combined, coordinated mapping efforts will establish relationships among park managers, GRI staff, NPS scientists, and non-NPS researchers that will continue to support critical decisions along NPS coastal areas.

## MEETING SUMMARY

As the cover of this report demonstrates, standard geologic maps do not sufficiently illustrate the dynamic nature and geological variability of coastal environments. Presently, a mapping template does not exist that illustrates short and long-term changes in coastal features and processes, or the connections among geologic, biological and physical system components. Without this product, coastal park managers do not have the essential information necessary to make effective coastal management decisions.

The main purpose of the Coastal Mapping Protocols meeting was to bring together a small group of experts including geologists, coastal scientists, coastal park managers, information technology specialists, and inventory and monitoring coordinators to organize and design a comprehensive and beneficial mapping program for coastal National Park units in Atlantic and Gulf regions. Most importantly, coastal park managers identified specific coastal management concerns and geologic mapping needs. This information was then used to construct a new and innovative coastal mapping project for NPS coastal parks.

The first day of the workshop consisted of a field trip to Canaveral National Seashore (Appendix 4) to discuss site-specific mapping needs and procedures, and to investigate the geomorphology and ecology of the area.

Day two began with a welcome from Bob Newkirk, the Superintendent of Canaveral National Seashore and John Stiner, Chief of Resource Management at CANA. This was followed by an introduction and workshop agenda discussion by the NPS co-coveners, Rebecca Beavers, Tim Connors, Joe Gregson and Bruce Heise. The day progressed with presentations, including current mapping products and technologies, resource management concerns, inventories and monitoring of national parks, coastal vulnerability indexing (CVI), and NPS vital signs. These presentations sparked participant discussion and debate on coastal mapping protocols and procedures. This day ended with a social gathering at the Eldora House, and a midnight "turtle watch" hosted by John Stiner and Don Mock along Canaveral National Seashore.

On the final day of the workshop, the participants were divided into three working groups (marine, estuarine, and landform) during the morning breakout session. Each group discussed mapping needs and dilemmas, and formulated a list of specific mapping units (p.20) for their respective coastal area. In the afternoon, all participants reconvened to compile a workable list of geologic features for future mapping products. In addition, topics such as digital mapping processes, interagency cooperative agreements, costs, and final report content were discussed.

## MOST IMPORTANT COASTAL MAPPING UNITS

The Geologic Resources Inventory will provide each coastal park unit with mapping products that define a park's geologic framework (i.e. bedrock geology) and/or geomorphic submerged and emergent features. When possible, available bathymetric, topographic and benthic habitat data will also be provided. This information will provide each park with the basic template to identify coastal change and shoreline dynamics.

This report includes known interagency and outside sources that may have access to or knowledge of existing mapping products. Additional sources should be identified to increase coastal mapping benefits to all partners.

### 1) Geologic Framework

*Mapping needs*
Coastal geologic mapping products should include surficial and bedrock geology. This geologic framework defines how the coast will evolve and will predispose some areas to more rapid change. Where feasible, Pleistocene and Holocene deposits should be differentiated and relict landforms should be assigned a consistent terminology. Surface and subsurface lithology should be included. In addition, regional geology should be discussed, using supplemental materials if necessary.

*Example of Use*
The geologic framework of older stratigraphic units often controls modern coastal dynamics and morphology. This is especially important on passive margins with limited sand supply such as is present over much of the Atlantic coast. Along Cape Hatteras National Seashore, more resistant units may influence sediment shoaling and shifts in shoreline position. For more information, please see Riggs, S., W.J.Cleary and S.W. Snyder, 1995. Influence of geologic framework on barrier shoreface morphology and dynamics. Marine Geology 126: 213-234.

*Possible Sources*
- National Park Service (NPS) – Geologic Resources Inventory (GRI)
- GEOINDEX and GEOREF databases
- U.S. Geological Survey (USGS)
- State Geological Surveys
- Ocean Drilling Project (ODP)
- Universities
- Private contractors

*Mapping Considerations*
Geologic mapping is time consuming and expensive. Although bedrock and surficial geologic maps are the base products of the GRI, to meet park needs in a cost-effective and productive manner, the National Park Service must form partnerships with other government agencies, universities, and private contractors.

*Techniques*
Currently, geologic framework protocols are not well defined for coastal areas, but it is critical information to predict coastal ecosystem evolution. The techniques used to map a region's geologic framework need to be refined through further studies. The shallow subsurface (~5-10') may be mapped using shallow seismic or ground penetrating radar (if substrate is suitable) or hand augers.

## 2) Geologic Features (Geomorphology)

*Mapping needs*
Workshop participants compiled an extensive list of geomorphic features that should be included in the final geologic mapping products (p.21). Due to cost and time limitations, only the most significant of these features will be included in a coastal park map. Obviously, not all of the features listed will be found in all coastal parks. In addition, all landforms should be mapped with a consistent terminology so that the maps may be integrated on a regional or national scale. Supplemental information may include alternative terminology for landforms within a specific region. Submerged and emergent features should be represented on the same or linked coverages. Specific features for each park's map will be identified at the GRI scoping meetings. GRI staff will integrate the identified coastal mapping units into the NPS Geology-GIS Data Model, the documented standard for digital geologic maps within the NPS.

*Example of Use*
The North Carolina Geologic Survey is developing techniques for coastal landform mapping at Cape Hatteras National Seashore that may serve as a template for additional coastal units. This mapping is part of a coastal mapping cooperative spearheaded by USGS.

*Possible Sources*
- NPS - GRI
- USGS
- State Geologic Surveys
- Universities
- Private contractors

*Mapping Considerations*
Coastal geomorphologists will be needed to identify and differentiate many coastal geologic features. Because most parks do not employ geologists, parks must have outside expertise to accomplish this image interpretation and subsequent field verification. Where regional names exist for similar features, a uniform terminology should be applied and documented in the NPS Geology-GIS Data Model.

*Techniques*
Recent aerial imagery, high resolution digital elevation data, seabed imagery, and ground truthing in the field may be utilized for the mapping of geomorphic features.

## IMPORTANT MAPPING UNITS

The GRI will attempt to obtain the following information for integration with coastal geomorphology and geologic framework map coverages. When accessible, the GRI will incorporate the best available bathymetric and topographic data, benthic habitat, shoreline engineering, and sediment characteristics into final mapping products. Where this information is not at a sufficient resolution, the GRI will seek to partner with other groups to acquire these data.

## 3) Bathymetry and Topography

*Mapping needs*

Maps should include seamless coverage of submerged to emergent features. It is critical that this link is made between NOAA bathymetric charts and USGS topographic maps. Joining these coverages may require additional work along the shoreline, since many coverages use different datums. When feasible, all maps should be rectified to the same scale, with all maps produced at a scale of 1:24,000 or greater (1:12,000, etc.). An official definition of the shoreline will be required to produce standard mapping products.

*Possible Sources*

- USGS – Digital Topographic Map Layers (Inventory & Monitoring Base Cartography Inventory)
- National Oceanic and Atmospheric Administration (NOAA) – Bathymetric Maps
- NPS – GRI
- NPS – Inventory and Monitoring (I&M) Program
- NPS – Natural Resource Program Center (NRPC) NPS – GIS Program (Information Technology Center)

*Mapping Considerations*

- The shoreline is difficult to define, and a consistent shoreline is difficult to measure. Most agencies use different datums for shoreline mapping. NOAA generally uses the Mean Lower Low Water (MLLW) mark as the datum for bathymetry charts, whereas USGS topographic maps extend to the Mean High Water (MHW) or Mean Sea Level (MSL) line. When these maps are joined, they will most likely not produce the same shoreline.

- In shallow nearshore environments it is difficult to map slight elevation variations. Vegetation may be helpful for determining minor elevation differences. Interferometric sonar mapping appears to be most effective in shallow areas between 0-30'depth.

- The frequency of coastal mapping is variable due to cost and time restrictions. Coastal areas should be mapped often (every 5-10 years?) because of short and long-term changes to topography and bathymetry caused by sediment transport and storm events. These changes begin approach the realm of monitoring, rather than inventory.

- Inconsistent methodologies and mapping standards produce different levels of accuracy and resolution. Historic maps must often be utilized although they were created using out-dated technologies. Maps produced at different scales must be rectified at high resolution to be beneficial for coastal managers.

- The National Academy of Sciences is currently defining coastal mapping standards for Federal, State and local governments. If these standards are approved, future mapping efforts will benefit from standardized digital information exchange between government agencies, and create more efficient and effective mapping and charting tools for our Nation's coasts. If national standards and data models are not available, the NPS will need to define and document its own coastal bathymetry/topography data model for consistent mapping and attribute data among NPS units.

*Techniques*

NOAA and the USGS have established a Bathy/Topo Java-based application that seamlessly merges bathymetric and topographic data from different sources using a Vertical Datum Transformation.

NOAA has expressed interest in a collaborative partnership with the NPS to provide seamless coverage for coastal National Parks.

## 4) Sediment Characteristics - Grain Size, Composition, and Distribution

*Mapping needs*
Sediment characteristics including grain size, sorting and color descriptions should be integrated with coastal geology maps. Available information on sediment distribution, budget, and sources and sinks should be included in the mapping product. An understanding of a system's sediment supply is critical for monitoring coastal areas and predicting shoreline change.

*Possible Sources*
- NPS – GRI
- NPS - Soil Resources Inventory (NRCS Soil Maps)
- NPS – Water Resource Inventories
- National Wetlands Inventory (NWI)
- USGS
- NOAA
- State agencies
- Ocean Drilling Project

*Mapping Considerations*
Sediment characteristics may change within small areas, making mapping difficult. Ground-truthing and laboratory analysis are time consuming and expensive. At a minimum, descriptions of sediment characteristics should be included in the legend of the coastal landform mapping discussed earlier.

*Techniques*
Field work during coastal landform mapping should include description of surface sediments and sediment cores (e.g., using hand augers or core drilling) to the extent that available resources allow. Side-scan sonar equipment can be used to define coarse or fine-grained sediments in submerged areas.

## 5) Benthic Habitat

*Mapping needs*
Important benthic habitats including coral reefs, shellfish beds, hardbottom, and submerged aquatic vegetation should be included in coastal landform maps. These features influence the hydrodynamic regimes within their localized areas, thereby determining sedimentation patterns. The location of these ecologically and economically vital resources must be known to determine the impacts that anthropogenic modifications may have on their survival. For example, heavy siltation caused by coastal development could suffocate shellfish beds, or excessive pollution may cause rapid die-off of coral reef populations. In addition, some aquatic vegetation such as eelgrass beds, are considered "keystone species" that promote increased biotic diversity and abundance in marine and estuarine environments. Coastal Park Managers must be aware of these resources and the effects that sediment transport may have on important ecological niches.

*Possible Sources*
- NPS – Natural Resource Inventories and I&M Networks

- NPS – NRPC
- NOAA
- NOAA's National Coastal Data Development Center (NCDDC) – Coral Reef Information System (CoRis)
- NWI

*Mapping Considerations*
Many vitally important benthic habitats are small in size, and scattered throughout the coastal area. Although certain acoustic and optical technologies are useful in locating these features, ground truthing using SCUBA or underwater videography is most likely necessary to detail the scope of these habitats.

## 6) Shoreline Engineering

*Mapping needs*
Shoreline engineering structures may have a significant impact on sediment, hydrodynamics and shoreline geomorphology. All anthropogenic modifications to the shoreline should be mapped including, but not limited to: jetties, groins, seawalls, spoil deposits, riprap, and culverts.

*Possible Sources*
- NPS -Facilities Management
- NPS-GRI (Landform mapping)
- State governments
- US Army Corps of Engineers (USACE)
- Department of Transportation (DOT)

*Mapping Considerations*
Some park areas have been significantly altered by anthropogenic modifications for many centuries. For example, Native American middens are found throughout Canaveral National Seashore. Like middens, some features are difficult to locate and identify, especially dredge spoils, seawalls and rip rap when they are covered by sediment and vegetation. However these anthropogenic modifications must be identified in order to understand and predict shoreline change.

## ADDITIONAL COASTAL MAPPING UNITS

The participants of the Mapping Protocols Workshop determined that a standard "geologic map" is not sufficient for highly dynamic coastal areas. Although the underlying geologic framework, surficial sediments, and geomorphology will provide the basis for understanding coastal geologic features, an integrative, "holistic" approach is necessary for effective coastal management due to the complex ecological interactions that govern coastal change. For a coastal *geology* map to be beneficial, it must integrate the biological and physical components of the coastal zone, which are closely related to associated landforms. The integration of landforms and associated ecosystem units into one comprehensive mapping product will aid park managers who are commonly confronted with multi-faceted coastal geology issues. To effectively resolve these issues, coastal managers require a broad understanding of the intricate links between sediment movement (erosion and accretion), grain size, biological habitats, hydrodynamic regimes, salinity, temperature, vegetative cover, tides and prevailing currents.

When possible, the following mapping themes should be integrated with coastal landform mapping products. Due to funding and time restraints, the GRI will provide this information only when it may be readily acquired or derived during coastal landform mapping, but may provide additional technical assistance to park managers wishing to obtain this data. In addition, park managers may seek direct partnerships with other NPS divisions, government agencies and universities to acquire this information. We have included known interagency and outside sources that may have access to, or knowledge of existing mapping products. Additional sources should be identified to increase coastal mapping benefits.

### 1) Vegetation

*Mapping needs*
Vegetation found in coastal environments such as wetlands, marshes, dunes, mangroves and maritime forests should be incorporated with coastal geology maps for the following reasons:

- Vegetation, especially hydrophytes, strongly influences sediment deposition and hydrodynamic regimes.
- Vegetative associations may reveal slight differences in surface elevation and salinity.
- Vegetation aids dune and shoreline stability.

*Example of use*
Wetland environments have distinct vegetation zones created by changes in elevation, salinity and hydroperiod. Therefore, wetland vegetation may possibly be used to identify topographic and oceanographic variables and identify landform types.

*Possible Sources*
- NPS/USGS Vegetation Inventory
- NPS Biological Resources Management Division
- USGS - Biological Resources Division
- National Wetlands Inventory
- Bureau of Land Management (BLM)
- U.S. Fish and Wildlife Service (USFWS)
- Universities
- State Surveys

*Mapping considerations*
Most vegetation mapping programs utilize aerial and satellite technologies that only show vegetation associations, not specific species. Vegetation maps of submerged aquatic vegetation may require additional funding, because they are not funded by most vegetation mapping projects. Many technologies, such as Airborne Topographic Mapping (ATM) and Light Detection and Ranging (LIDAR) elevation data, have a difficult time resolving the extent of vegetation cover. However, new technologies such as Experimental Advanced Airborne Research Lidar (EAARL), will provide better resolution of vegetation cover. Cooperative data acquisition and mapping among the NPS/USGS Vegetation, NPS Geologic Resources, and NPS Soils inventories may be able to provide coastal parks with detailed data products to meet the management needs of coastal parks.

## 2) Threatened and Endangered Species Habitat

*Mapping needs*
Coastal resource inventories need to include threatened and endangered species distribution maps. Any anthropogenic modification to the coastal zone within, or adjacent, to park boundaries may have detrimental effects on protected species.

*Example of Use*
When sand replenishing on beaches is absolutely necessary within, or adjacent to, a park boundary, resulting changes in sediment load may have detrimental impacts on threatened and endangered species. Knowledge of preferred breeding grounds and seasonal trends in populations may influence the feasibility of shoreline engineering projects. Differences in grain size and sediment type may completely alter the quality and amount of habitat available for threatened and endangered species.

*Possible Sources*
- NPS Species Inventory
- NPS Biologic Resources Management Division
- NPS Vital Signs Monitoring Program
- Non-Profit Organizations
- Nature Conservancy

*Mapping considerations*
Many threatened and endangered species (especially marine organisms) are elusive and difficult to find, let alone map. Extant maps of threatened and endangered species are much more thorough for terrestrial species.

## 3) Oceanographic Variables

*Mapping needs*
Relative sea-level rise, temperature and salinity patterns, currents, tidal regimes, sediment budget, fresh/salt water interface within estuarine systems and upwellings are examples of oceanographic variables that are not well documented in most coastal park units.

*Example of use*
Dr. Greg Stone at Louisiana State University has used oceanographic instrumentation to measure physical processes near West Ship Island in Mississippi. These measurements were combined with beach profiles to document sediment dynamics near Fort Massachusetts. This fort is threatened by erosion, and available physical processes measurements were used to design a beach nourishment project in 2002 to protect the fort.

*Possible Sources*

- NPS/USGS – The Coastal Vulnerability Index (CVI) calculates the effects of relative sea level rise, tidal range, coastal slope, wave heights, shoreline erosion rates and geomorphology (relative erodibility) on the shoreline.
- NPS I&M Program – The I&M is funding acquisition of the 1:24,000 National Hydrography Dataset as part of its Water Resources inventories.
- NPS Vital Signs Monitoring Program
- NOAA

*Mapping considerations*

Salinity, water temperatures, currents and wave patterns may change daily, seasonally and/or yearly. Relative sea-level rise may be small (mm) and difficult to accurately measure. However, even the smallest sea-level rise may have a large impact on fragile estuarine and coastal environments. Although it is costly to maintain oceanographic instruments, a nationwide effort to develop a coastal observations system must be supported.

## 4) Park Boundaries

*Mapping needs*

Park boundaries must be determined to establish park jurisdiction and property rights. Offshore boundaries are extremely important to resolve legal issues such as mining rights, law enforcement, USACE dredging and disposal projects, etc.

Coastal maps should incorporate areas outside of park boundaries. These areas should include external threats such as large developments and production plants. This is important when determining sediment transport (non-point source pollution, contaminated sediments, dredging and disposal impacts outside of park, etc.) The total area that should be included is an elastic boundary defined by system dynamics. The specific area included in each park map should be resolved during park scoping sessions. When possible, the map should include geologic and bathymetric data up to 5 miles offshore. Data collected outside of park boundaries may be mapped at a lower resolution. Often, parks define this as their “quadrangle of interest.”

*Example of use*

The National Marine Fisheries Service notified Gulf Islands National Seashore (GUIS) of a U.S. Army Corps of Engineers (USACE) Preliminary Restoration Plan for the Fort McRee Dredged Material Disposal Area. USACE had proposed a variety of disposal scenarios that were located within congressionally authorized GUIS boundaries. In order to ensure protection of park resources and values within park boundaries, the NPS requested active participation in the Corps’ planning process and monitoring activities. Without accurate knowledge of park boundaries, GUIS may not have been legally entitled to project intervention.

*Possible Sources*

- NPS – I&M Program
- NPS - GIS Program (Information Technology Center)
- Minerals Management Service (MMS) – Offshore boundaries
- BLM – Land boundaries
- USGS National Map

*Mapping considerations*
The Bureau of Land Management (BLM) maps to the Mean High Water (MHW) mark (what they refer to as the vegetation line), whereas the Minerals Management Service (MMS) determines offshore boundaries based on NOAA's Mean Lower Low Water (MLLW) mark. Therefore, a large mapping gap exists between the MHW and MLLW lines. In addition, it is difficult to find a successful mapping methodology for the shallow nearshore zone (0-30').

## 5) Cultural Resources and Park Infrastructure

*Mapping Needs*
Coastal Maps should integrate park infrastructure including, but not limited to, roads, restrooms, parking lots and visitor interpretation centers. Additional cultural resources such as archaeological sites, shipwrecks, quarries, and developed areas should also be accessible in integrated map coverages.

*Example of Use*
Erosional hot-spots, barrier island migration, and/or relative sea-level rise may influence relocation of park infrastructure and historic landmarks. Cape Hatteras National Seashore recently relocated the historic Cape Hatteras lighthouse due to natural barrier island migration, storm events and shoreline engineering. The integration of park infrastructure and important cultural resources with geologic maps is necessary to identify at-risk areas, and to make timely preparations and management decisions.

*Possible Sources*
- NPS GIS Program (National, Regional, and Park-based)
- NPS Facilities Management
- NPS Cultural Resources Programs
- NPS Submerged Resources Center
- NPS Base Cartography Inventory
- NPS Water Quality Inventory
- NPS I&M Program
- DOT

## 6) Miscellaneous Features

*Mapping needs*
Coastal mapping products should include cave and karst resources, natural springs, paleontological sites, flood-prone areas, and known mineral deposits.

*Example of use*
In January 1990, two visitors at Cape Hatteras National Seashore made a startling discovery – they found one of the most complete fossil walrus skulls found in the eastern United States. This fossil has shed light on past climate conditions, Gulf Stream current patterns, and our geological past. Coastal park managers must be able to quantify the risk to these valuable resources from weathering and erosion. When located in coastal environments, fossils are easily exposed, and then lost, to wave action and storm events. Therefore, it is important for coastal managers to be familiar with a park's paleontological resources and to understand the threats confronting fossil preservation in coastal

environments. Currently, park/regional GIS and I&M staff are GPS mapping paleontologic resources to assist park-monitoring efforts.

*Possible Sources*

- NPS – Known cave and karst resources, paleontological sites and mineral deposits, natural springs, shipwrecks
- NPS Vital Signs Monitoring Program
- NPS Geologic Resources Division (cave and karst, paleontology, disturbed lands, minerals oil and gas, etc.)
- MMS – Mineral deposits and claims
- NOAA – shipwrecks
- Federal Emergency Management Agency (FEMA) – Flood areas

*Mapping considerations*

Some sites may contain sensitive resources and location and attribute data that should only be accessible to park managers and NPS employees, whereas other sites may be for visitor use and enjoyment and should be made publicly available.

## COASTAL GEOLOGY MAPPING FEATURES

The following is a list of coastal geology mapping features that may be incorporated into the NPS Geology-GIS Data Model and into final digital mapping products for each park unit. Not all of the features listed will be found within every coastal park. This checklist may be used as a reference for coastal park managers to compile a preliminary assessment of the geologic features found within their park boundaries to help facilitate the Geologic Resources Inventory.

GRI scoping meetings are intended to assess the significant geologic features and processes located within National Park units. As of 2002, 78 parks have been scoped. 273 parks, including approximately 77 coastal units, with "significant" natural resources will ultimately be evaluated. Therefore, many managers of small or cultural coastal park units will be responsible for initiating the inventory and monitoring processes within their units. This will be successful if communication is established with national and regional coastal geology coordinators (Rebecca Beavers, (GRD) and Linda York (SER)), and interagency and university partnerships are formed. For assistance with coastal inventory and mapping projects, please see the list of federal contacts (Appendix 1).

The GRI will provide mapping products that include the geologic framework (both surficial and bedrock) and coastal landforms found within each park unit. When available, the GRI will also provide bathymetric and topographic data, sediment characteristics and benthic habitat maps to each park. Additional mapping units found in the following list may possibly be supplied by other NPS divisions or Natural Resource inventories (Water, Soil, Biological Resources, etc.), or from cooperative government agencies, universities and/or private consultants. GRI staff will work with coordinators of other Natural Resource inventories to identify and initiate possible integrated data collection and mapping projects. Cooperative projects may allow significant cost savings for the inventories and higher quality data products for park managers.

## ANTHROPOGENIC FEATURES (Submerged to Emergent)

- ❑ Hazardous Materials
- ❑ Dredge Spoils
- ❑ Public (Non-Sensitive) and Sensitive Archeological Sites
- ❑ Middens
- ❑ Shipwrecks
- ❑ Shoreline Engineering Structures
  - ❑ - Jetties
  - ❑ - Groins
  - ❑ - Seawalls
  - ❑ - Piers
  - ❑ - Rip Rap
  - ❑ - Sand Tubes
- ❑ Propeller Scars
- ❑ Dredged Channels
- ❑ Borrow Sites

- ❑ Mosquito Ditches
- ❑ Impoundments
- ❑ Canals
- ❑ Artificial Levees
- ❑ Undifferentiated Mounds
- ❑ Undifferentiated Excavations
- ❑ Roads (Paved/Dirt)
- ❑ Railroads
- ❑ Docks/Marinas/Anchorages
- ❑ Dumps
- ❑ Culverts
- ❑ Dams
- ❑ Human Debris
- ❑ Artificial Reef
- ❑ Dune Walk-over
- ❑ Parking Lots
- ❑ Buildings
- ❑ Historic Structures (Lighthouses, Forts, Houses, etc.)

**SUPRATIDAL ENVIRONMENTS**

- ❑ Landslide Excavation & Deposits
- ❑ Vegetated/Unvegetated Beach Ridge
- ❑ Natural Debris
- ❑ Vegetated/Unvegetated Supratidal Flat
- ❑ Bluffs
- ❑ Dunes
    - ❑ - Dune Ridge
    - ❑ - Coppice
    - ❑ - Complex (Discontinuous)
    - ❑ - Isolated
    - ❑ - Relict
    - ❑ - Secondary
    - ❑ - Active Blowout/Blowout Dune
    - ❑ - Parabolic Dunes
    - ❑ - Dune Swale
    - ❑ - Deflation Troughs or Flats
    - ❑ - Low Vegetated Ridge

- ❑ - Foredune
- ❑ - Vegetated/Unvegetated Dunes
- ❑ - Primary Dunes
- ❑ - Secondary Dunes

## INTERTIDAL ENVIRONMENTS

**Beach Environments**

- ❑ Sediment Depth and Lithology
- ❑ Grainsize
  - ❑ - Sand Beach
  - ❑ - Mixed Sand and Gravel Beach
  - ❑ - Gravel Beach
  - ❑ - Boulder Beach
- ❑ Boulder Ramps
- ❑ Washover Fan/Overwash Deposits
- ❑ Spits
- ❑ Berm
- ❑ Ridges and Swales (Swash Bar)
- ❑ Beachrock

**Marsh Environments**

- ❑ High/Low Marsh
- ❑ Marsh/Wetland Levee
- ❑ Salt Pannes
- ❑ Salt Ponds
- ❑ Wetland Creek

## INTERTIDAL/SUBTIDAL FLAT ENVIRONMENTS

- ❑ Bioherms (Oyster, Mussel, etc.)
- ❑ Channel Levee
- ❑ Algal Flat
- ❑ Eelgrass Flat
- ❑ Seaweed Flat
- ❑ Veneered Ramp

- ❑ Wind-Tidal Flat
- ❑ Tidal Flat
- ❑ Vegetated/Unvegetated Bottom
- ❑ Sediment Flat Type
    - ❑ - Coarse-Grained Flat
    - ❑ - Mud Flat

**SUBTIDAL ENVIRONMENTS**

- ❑ Tidal Channels
- ❑ Estuarine Channel
    - ❑ - Estuarine Flood Channel
    - ❑ - Estuarine Ebb Channel
- ❑ Inlet Channel
- ❑ Relic Inlet Channel
- ❑ Channel Slope
- ❑ Ebb-Tide Delta
- ❑ Flood-Tide Delta
- ❑ Coral Reefs
- ❑ Hard Bottom
- ❑ Soft Bottom

**COASTAL-RIVERINE SYSTEMS**

- ❑ Strandplain Beach
- ❑ Swamp Forest
- ❑ Upland Swamps
- ❑ Creeks-Rivers
- ❑ Riverine Cutbanks (Ledges)
- ❑ Wave-Cut Cliff
- ❑ Fluvial-Estuarine Channel
- ❑ Point or Lateral Bars
- ❑ Oxbow Lake
- ❑ Floodplain
- ❑ Crevasse Splay
- ❑ Alluvium

## MISCELLANEOUS

- ❑ Spillover Lobe
- ❑ Geologic Hazards (Sinkholes, Slide Areas, etc.)
- ❑ Relict Reefs and Features (Pleistocene)
- ❑ Abandoned Channels
- ❑ Karstic features
    - ❑ - Rillen-Karren
    - ❑ - Poljes
    - ❑ - Eolian Calcarenite
    - ❑ - Sea Caves
- ❑ Mineral/Hydrocarbon Resources
- ❑ Sand Resources (areas of identified potential or exploited)
- ❑ Groundwater Seeps/Springs
- ❑ Geologic Framework
    - ❑ - Structure (faults, folds, etc.)
    - ❑ - Stratigraphy (delineated by structure contour and isopach maps; will show paleochannels)

## BOUNDARIES

- ❑ Park Boundary
- ❑ Mean High Water and Mean Low Water Lines
- ❑ Shoreline
- ❑ Submarine Escarpments

## SENSITIVE PARK SITES

- ❑ Caves
- ❑ Paleontological Resources
- ❑ Cultural Resources
    - ❑ - Shipwrecks
- ❑ Mineral Deposits

## Appendix 1
## FEDERAL CONTACTS

| AGENCY AND DIVISION | Contact | *Position* |
|---|---|---|
| **National Park Service**<br><br>**Geological Resources Division**<br>**WASO – Lakewood, CO** | **Rebecca Beavers**<br>Coastal Geologist<br>303-987-6945<br>rebecca_beavers@nps.gov | *Assists coastal park managers with coastal erosion issues; coordinates current coastal mapping protocols program for the NPS; USGS Coastal and Marine liaison.* |
| | **Pete Biggam**<br>Soil Scientist<br>303-987-6948<br>pete_biggam@nps.gov | *Coordinates soil surveys and soil research; will provide technical expertise and guidance in park soil inventories.* |
| | **Julia Brunner**<br>Policy and Regulatory Specialist<br>303-969-2012<br>Julia_F-Brunner@nps.gov | *Provides National and park-specific policy and regulatory expertise in coastal management issues; can provide assistance with park boundary and NPS jurisdiction information.* |
| | **Tim Connors**<br>Geologist - GRI<br>303-969-2093<br>tim_connors@nps.gov | *Provides information on existing park digital products; coordinates GRBIB; plans and conducts park scoping meetings.* |
| | **Bruce Heise**<br>Geologist - GRI<br>303-969-2017<br>bruce_heise@nps.gov | *USGS and AAGS liaison; coordinates and conducts park scoping meetings; provides GRI administrative support.* |
| | **Ron Kerbo**<br>Cave Specialist<br>303-969-2097<br>ron_kerbo@nps.gov | *Assists in cave and karst resource management, and protection; coordinates cave and karst research and cave cartographic projects; will assist in cave/karst projects and management planning documents; will provide cartographic information to parks.* |
| | **Greg McDonald**<br>Paleontologist<br>303-969-2821<br>greg_mcdonald@nps,gov | *Assists in paleontologic resource inventory and protection; coordinates paleontology research programs; has proposed a standardized GPS paleontology mapping program that will automate database management; will assist parks with mapping paleontological resources.* |
| | **Dave Steensen**<br>Geologist – Disturbed Lands<br>303-969-2014<br>dave_steensen@nps.gov | *Will provide action plan to parks to assist in disturbed lands mapping; administers funding for disturbed lands inventories; developing standardized inventory template and guidance sheets for coastal parks.* |
| **National Park Service**<br><br>**Southeast Regional Office**<br>**Atlanta, GA** | **Crista Carroll**<br>Geographer<br>404-562-3113 X528<br>crista_carroll@nps.gov | *GIS coordinator for National Parks within the Southeast Region; provides technical assistance with data acquisition and standards; arranges GIS training courses for park managers.* |
| | **Larry West**<br>Inventory and Monitoring Program Natural Resource Specialist<br>404-562-3113 x526<br>larry_west@nps.gov | *Inventory and Monitoring Coordinator for the Southeast Region.* |
| | **Linda York**<br>Coastal Geomorphologist<br>404-562-3113 x537<br>linda_york@nps.gov | *Provides scientific expertise to assist in resolving coastal management issues; assists in pooling GIS technologies and technical expertise for small parks.* |
| **National Park Service**<br>**Northeast Regional Office**<br>**Boston, MA** | **Mary Foley**<br>Chief Scientist<br>617-223-5024<br>mary_foley@nps.gov | *Chief Scientist of the Boston Support Office of the Northeast Region.* |

## Appendix 1
## FEDERAL CONTACTS

| AGENCY AND DIVISION | Contact | *Position* |
|---|---|---|
| **National Park Service Water Resources Division** | **Jim Tilmant**<br>Fisheries Biologist<br>970-225-3547<br>jim_tilmant@nps.gov | *Provides information on status of NPS coral reef mapping products; assists in coral reef protection and management; coordinates NPS coral reef research* |
| | **Dean Tucker**<br>Natural Resource Specialist<br>970-225-3516<br>dean_tucker@nps.gov | *Provides Horizon reports (water quality assessments) to the NPS.* |
| | **Joel Wagner**<br>Hydrologist<br>303-969-2955<br>joel_wagner@nps.gov | *Coordinates wetland projects and information for the NPS; will assist in coordinating research and management of wetland resources; provides contact information for obtaining USFWS National Wetlands Inventory mapping products and data.* |
| **National Park Service Information Technology Center WASO – Lakewood, CO** | **Leslie Armstrong**<br>GIS Coordinator<br>970-969-2965<br>leslie_armstrong@nps.gov | *Coordinates GIS mapping products and NPS standards; organizes and conducts GIS training workshops for NPS park employees; coordinates data acquisition with outside sources; coordinates NPS data clearinghouse; has acquired 3-4 years of NPS coastal data for park distribution.* |
| **National Park Service Natural Resource Information Division** | **Joe Gregson**<br>Natural Resources GIS coordinator<br>970-225-3559<br>joe_gregson@nps.gov | *GIS and database technical support; assists in park scoping coordination.* |
| | **Mike Story**<br>Remote Sensing Specialist<br>303-969-2746<br>mike_story@nps.gov | *Provides vegetation mapping products to parks; coordinates vegetation inventory, mapping and product distribution.* |
| **United States Geological Survey** | **John Brock**<br>Geologist<br>727-803-8747 x3088<br>jbrock@usgs.gov | *Can provide technical expertise and research coordination with LIDAR; conducting numerous mapping projects with NPS and NASA.* |
| | **John Haines**<br>Coastal and Marine Program Manager<br>703-648-6422<br>Jhaines@usgs.gov | *Program manager of USGS Coastal and Marine Geology.* |
| | **Asbury Sallenger**<br>Geologist<br>727-803-8747 x3015<br>asallenger@usgs.gov | *Administers National Shoreline Assessment Program.* |
| **National Oceanic And Atmospheric Association**<br><br>**National Ocean Service** | **Peter L. Grose**<br>Estuarine Bathymetry - Special Projects<br>(301) 713-3000 x132<br>mapfinder@nooaa.gov | *Provides DEMs of estuarine topography from more than 71 estuaries, many located in the Southeastern US.* |
| | **Bruce Parker**<br>Chief, Coast Survey Development Lab<br>301-713-2801 x121<br>Bruce.Parker@noaa.gov | *Development of Bathy/Topo mapping tool to provide seamless coverage between NOAA bathymetric maps and USGS topographic maps; suggests USGS-NOAA-NPS partnership to apply Bathy/Topo program to coastal National Park mapping products.* |

## Appendix 1
## FEDERAL CONTACTS

| **AGENCY AND DIVISION** | **Contact** | *Position* |
|---|---|---|
| **National Oceanic And Atmospheric Association**<br><br>**National Coastal Data Development Center** | **John Stinus**<br>Director of NCDDC<br>228-688-3450<br>Joe.Stinus@noaa.gov | *The NCDDC will connect coastal managers to available digital data information; major programs of focus include the following: coastal risk, harmful algal blooms, homeland security, marine invasive species, fish habitat, integrated sustained ocean observing system, and coral reefs.* |
| **National Oceanic And Atmospheric Association**<br><br>**Coastal Services Center** | http://www.csc.noaa.gov/<br><br>843-740-1200 | |
| **Mineral Management Service** | **Leland F. Thormahlen**<br>Chief, Mapping and Boundary Branch<br>303-275-7120<br>Leland.Thormahlen@mms.gov | *May provide assistance to parks to map offshore boundaries and establish park jurisdiction.* |
| | **Robert Johnson**<br>Cartographer, Mapping and Boundary Branch<br>303-275-7186<br>Robert.E.Johnson@mms.gov | *May provide assistance to parks to map offshore boundaries and establish park jurisdiction.* |
| **Bureau Of Land Management** | **Daniel Mates**<br>Cadastral Surveyor<br>Dan_Mates@co.blm.gov | *BLM will resurvey land when requested; map shoreline at MHW mark (what they consider the vegetation line); would like to coordinate with NOAA definition of official MHW.* |
| **US Fish & Wildlife** | http://www.fws.gov/ | *National Wetlands Inventory http://www.nwi.fws.gov/* |
| **US Army Corps Of Engineers** | http://www.usace.army.mil/ | |

## Appendix 2
## WORKSHOP PARTICIPANTS

| LAST NAME | FIRST NAME | AGENCY | AFFILIATION | TITLE | PHONE | E-MAIL |
|---|---|---|---|---|---|---|
| Allen[1] | Jim | federal | USGS-BRD | Geologist | 617-223-5058 | james_allen@usgs.gov |
| Armstrong | Leslie | federal | NPS-ITC | GIS | 303-969-2964 | leslie_armstrong@nps.gov |
| Beavers | Rebecca | federal | NPS-GRD | Geologist | 303-987-6945 | rebecca_beavers@nps.gov |
| Bilecki | Michael | federal | NPS-FIIS | Natural resources | 631-289-4810 ext. 234 | michael_bilecki@nps.gov |
| Brock | John | federal | USGS-CMG | Geologist | 727-803-8747 ext. 3088 | jbrock@usgs.gov |
| Bryant | Richard | federal | NPS-TIMU | Natural resources | 904-221-7567 ext. 15 | richard_bryant@nps.gov |
| Carroll | Crista | federal | NPS-SER | GIS | 404-562-3113 ext.528 | crista_carroll@nps.gov |
| Connors | Tim | federal | NPS - GRD | Geologist | 303-969-2093 | tim_connors@nps.gov |
| Conzelmann | Paul | federal | NPS-SER | Network coordinator | 337-266-8839 | paul_conzelmann@nps.gov |
| Daniels | Carol | federal | NPS-SER | CESU coordinator | 305-361-4904 | carol_daniels@nps.gov |
| Davis | Gary | federal | NPS-WASO/CHIS | Marine ecologist | 202-208-3574 | gary_davis@nps.gov |
| DeStoppelaire | Georgia | federal | USGS-CMG | Geologist | 727-803-8747 | gdestoppelaire@usgs.gov |
| DeVivo | Joe | federal | NPS-SER | Network coordinator | 404-562-3113 ext. 739 | joe_devivo@nps.gov |
| Duffy | Mark | federal | NPS-ASIS | GIS | 410-641-1443 ext. 219 | mark_duffy@nps.gov |
| Ebert | Jim | federal | NPS-CAHA | Natural Resources | 252-473-2111 ext. 132 | jim_ebert@nps.gov |
| Farrell | Kathleen | state | AASG-NCGS | Geologist | 919-733-7353 ext. 23 | kathleen.farrell@ncmail.net |
| Gregson | Joe | federal | NPS, - NRID | Physical scientist | 970-225-3559 | joe_gregson@nps.gov |
| Haines | John | federal | USGS-Coastal and Marine Geology | Geologist | 703-648-6422 | jhaines@usgs.gov |
| Harris | Melanie | federal | USGS-CMG | Geologist | 727-803-8747 | mharris@usgs.gov |
| Heise | Bruce | federal | NPS - GRD | Geologist | 303-969-2017 | bruce_heise@nps.gov |

1 Please see p.2

## Appendix 2
## WORKSHOP PARTICIPANTS

| LAST NAME | FIRST NAME | AGENCY | AFFILIATION | TITLE | PHONE | E-MAIL |
|---|---|---|---|---|---|---|
| Hoffman | Bill | state | AASG-NCGS | Geologist | 919-733-7353 ext.25 | bill.hoffman@ncmail.net |
| Hoggard | Riley | federal | NPS-GUIS | Natural Resources | 850-934-2617 | riley_hoggard@nps.gov |
| Hutcherson | Charlie | academic | FIT/Coastal Technology Corporation | Coastal engineer | 321-751-1135 | chutcherson@coastaltechcorp.com |
| Kevill | Cliff | federal | NPS-FOPU | Park ranger | 912-786-5787 | cliff_kevill@nps.gov |
| Littman | Sherri | academic | NPS-TIMU | Geocorps GIP | 904-641-7115 | caribe.l@att.net |
| Mcmullen | Ken | federal | NPS-PAIS | Natural resources | 361-949-8173 | ken_mcmullen@nps.gov |
| Milstead | Bryan | federal | NPS-NER | Network coordinator | 410-874-4603 | bryan_milstead@nps.gov |
| Morrison | Doug | federal | NPS-EVER | Marine Biologist | 305-852-0327 | douglas_morrison@nps.gov |
| Nelson | Kim | consult | NPS-GRD | Geologist | 303-969-2315 | kim_nelson@partner.nps.gov |
| O'Neal | Jerry | federal | NPS-SER | Chief Scientist | 404-562-3113 ext. 517 | Jerry_oneal@nps.gov |
| Parkinson | Randy | consultant | Coastal Technology Corporation | Geologist | 321-751-1135 | rparkinson@coastaltechcorp.com |
| Patterson | Matt | federal | NPS-SER | Network coordinator | 305-230-1144 ext. 3082 | matt_patterson@nps.gov |
| Phillips | Eleyne | federal | USGS-CMG | Geologist | 650-329-4921 | ephillips@usgs.gov |
| Riggs | Stan | academic | Eastern Carolina University | Geologist | 252-328-6015 | riggss@mail.ecu.edu |
| Schaub | Ron | Consultant federal | Dynamac Corp-NASA and Kennedy Space Center | Remote Sensing Analyst | 321-867-2112 | ronald.schaub-1@ksc.nasa.gov |
| Stiner | John | federal | NPS-CANA | Natural Resources | 321-267-1110 | john_stiner@nps.gov |
| West | Larry | federal | NPS-SER | IM coordinator | 404-562-3113 ext. 527 | larry_west@nps.gov |
| York | Linda | federal | NPS-SER | Geologist | 404-562-3113 ext. 537 | linda_york@nps.gov |

## Appendix 3: Workshop Agenda

*AGENDA*
**National Park Service**
**Coastal Mapping Protocols Meeting**
**Canaveral National Seashore**
**June 25-27**

**June 25**

| | |
|---|---|
| 7:30 – 4:40 | **Field Trip:** Canaveral National Seashore (Appendix 4) |

**June 26**

| | |
|---|---|
| 8:00 | **Welcome:** Bob Newkirk and John Stiner (NPS-CANA) |
| 8:10 | **Introductions & Purpose:** Bruce Heise, Rebecca Beavers |
| 8:20 | **Coastal Geology Overview of NPS Resources**: Rebecca Beavers<br>• Overview of Northeastern Coastal Park Geological Resources, Jim Allen, USGS-BRD<br>• Overview of Southeastern Coastal Park Geological Resources, Linda York, NPS-SER |
| 8:50 | Geologic Resource Inventory Program, Bruce Heise (NPS-GRD), Tim Connors (NPS-GRD), Joe Gregson (NPS-NRID) |
| 9:30 | Looking at Soil Resources as a Component in Coastal Resources Inventory, Ken McMullen, NPS-PAIS |
| 9:45 | GIS Program ***and*** Data Standards, Leslie Armstrong, NPS-ITC |
| 10:00 | Break |
| 10:15 | **Resource Managers Concerns**<br>*Discussion leaders*- Mike Bilecki (NPS-FIIS) and Cliff Kevill (NPS-FOPU) |
| 11:15 | Southeast Region NPS Inventory and Monitoring Program, Larry West, NPS-SER |
| 11:30-1:00 | **Lunch** |
| 1:00 | Northeast Region Coastal & Barrier Network: Geomorphology Monitoring Program, Mark Duffy, NPS-ASIS |
| 1:30 | Vital Signs Monitoring and Marine Mapping Based on Airborne Remote Sensing, John Brock, USGS-CMG |
| 2:00 | Existing Coastal Map Products in Other Agencies, Linda York, NPS-SER |
| 2:30-3:00 | **Break and Posters** |

## Appendix 3: Workshop Agenda

| | |
|---|---|
| 3:00 | NCGS/USGS/ECU Coastal Mapping of NPS units: Cape Hatteras National Seashore, Kathleen Farrell (NCGS) and Bill Hoffman (NCGS) |
| 3:30 | **Cape Lookout National Seashore Mapping**, Stan Riggs, ECU |
| 4:00 | Mapping Relative Coastal Vulnerability to Future Sea-Level Rise in the National Seashores, Rebecca Beavers, NPS-GRD |
| 4:15 - 4:45 | **Marching Orders/ Identify Working Groups** |

**June 27**

| | |
|---|---|
| 8:00-11:30 | **Breakout Sessions** to identify physical coastal features that can be captured on a map to assist park managers in making sound resource decisions. |
| 11:30-1:00 | **Lunch** |
| 1:00 - 4:00 | **Discussion** |

1. Boundary Issues
2. Priorities
3. How to obtain raw data for map
4. Inventory report topics
5. NRBIB-GRBIB

# Appendix 4: Field Trip Description

## Field Trip to Canaveral National Seashore – June 25, 2002

A field trip to Canaveral National Seashore (CANA) was held on the first day of the Coastal Mapping Protocols Workshop. Dr. Randy Parkinson, a geologist with Coastal Technology Corporation, introduced 25 participants to the geomorphology and ecology of this area. The day was spent investigating the coastal areas of Canaveral, by traversing an east-to-west transect of the southern portion of the park.

The four distinct geomorphic terrains in this region include 1) dune, 2) ridge and swale, 3) western, and 4) marsh. The *dune* terrain consists of recent, wave-dominated shorelines and aeolian dunes. The *ridge and swale* terrain is characterized by undulating topography resulting from a progradational beach ridge complex formed during a Pleistocene sea level high stand. The *western* terrain is typified by undistinguishable beach ridges and sinkhole depressions. Finally, the *marsh* terrain contains numerous circular marshes and lakes, resulting from underlying late-Cenozoic sub-surface karstic formations. Each of these unique areas is home to distinct ecosystems, demonstrating the vital relationship between geology and ecology.

The field trip included stops at the following locations:

1. **Canaveral beach** (pavilion) – The initial stop provided an overview of the modern coastal dune system and late Pleistocene ridge and swale geomorphic terrains. The dune system is narrow (1 primary ridge) and consists of classic clastic beach sediments, flora and fauna.

2. **Marsh impoundments –** A drive within the ridge and swale terrain provided a view of impounded wetlands, open water and hammock environments. Much of the hydrology in this geomorphic terrain has been altered by infrastructure and water management-structures that alter water levels and hydroperiod.

3. **Riverbank** (near bridge) – In addition to the unconsolidated late Pleistocene and Holocene sediments of the region, outcrops of coquina are exposed seaward of the modern coastal dune system and lie at or very near the surface at most locations. At Haulover channel, constructed earlier this century, exposures of coquina rock and residual soils are present along the margins of this anthropogenic feature. The age of this limestone is estimated at 120kbp, and it is thought to have formed within the coastal zone during a former sea level highstand. This location is at the boundary between the ridge and swale and western geomorphic terrains.

4. **Marsh** – In driving westward from the coquina outcrop, participants crossed the western terrain, a mesic floral environment established upon unconsolidated quartz sand and thin (<10 – 30 cm) residual organic-rich soil. Still further west, along the landward margin of the Refuge lies impounded marsh, the fourth and final geomorphic terrain. This area has been aggressively managed for mosquito and waterfowl for more than 5 decades and is highly deranged. Most of the salt- and fresh-water wetlands, hammock, or open water in this landscape is an artifact of surface water management.

Numerous discussions arose throughout the field trip concerning difficulties involved in mapping coastal areas. For example, what defines a natural landscape, and how do you recognize a disturbed landscape? Due to extensive anthropogenic manipulations (impoundments, dikes, dune building, middens, levees, etc.) there are few areas in Canaveral National Seashore left unaltered. In addition, this trip stressed the importance of combining surficial geology with the underlying geologic framework in order to effectively manage this coastal environment. It appears that most of the geomorphic features found within this vicinity result from the interactions between surficial sediment deposition, late-Quaternary sea level changes, and the dissolution of late-Cenozoic limestone.

Currently, Canaveral National Seashore (CANA) is managed through multi-agency cooperation between the National Park Service (NPS), National Aeronautics and Space Administration (NASA) and the US Fish and Wildlife Service (FWS). Kennedy Space Center is located adjacent to the southern boundary of CANA. NASA owns the lower two-thirds of the lands that the NPS manages including various support facilities, camera sites, and observation towers that require restricted access for National security concerns. In addition, FWS manages water levels in lagoons and impoundments that provide extensive bird habitat on Merritt Island National Wildlife Refuge.

# Appendix 5: Establishing a Geologic Baseline of Cape Canaveral's Natural Landscape: Black Point Drive

**2000 NASA/ASEE SUMMER FACULTY FELLOWSHIP PROGRAM**
**JOHN F. KENNEDY SPACE CENTER**
**UNIVERSITY OF CENTRAL FLORIDA**

## ESTABLISHING A GEOLOGIC BASELINE OF CAPE CANAVERAL'S NATURAL LANDSCAPE: BLACK POINT DRIVE

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## ABSTRACT

The goal of this project is to identify the process responsible for the formation of geomorphic features in the Black Point Drive area of Merritt Island National Wildlife Refuge/Kennedy Space Center (MINWR/KSC), northwest Cape Canaveral. This study confirms the principal landscape components (geomorphology) of Black Point Drive reflect interaction between surficial sediments deposited in association with late-Quaternary sea-level highstands and the chemical evolution of late-Cenozoic sub-surface limestone formations.

The Black Point Drive landscape consists of an undulatory mesic terrain which dips westward into myriad circular and channel-like depression marshes and lakes. This geomorphic gradient may reflect: (1) spatial distinctions in the elevation, character or age of buried (pre-Miocene) limestone formations, (2) dissolution history of late-Quaternary coquina and/or (3) thickness of unconsolidated surface sediment. More detailed evaluation of subsurface data will be necessary before this uncertainty can be resolved.

## 1.0 INTRODUCTION

The origin of Merritt Island National Wildlife Refuge and Kennedy Space Center's (MINWF/KSC) unique ecosystems can be attributed in large part to the region's distinct geomorphology and associated geologic processes. The goal of this project is to identify the processes responsible for the formation of geomorphic features in the Black Point Drive area of MINWR/KSC, northwest Cape Canaveral (Figure 1). Without a basic knowledge of the origin and evolution of these features, any effort to manage the landscape or restore the function and value of an ecosystem becomes problematic. For example:

a. What did the *natural* landscape look like before human alteration?
b. What *natural* processes contributed to the formation of this landscape?
c. How do we recognize a *disturbed* landscape?
d. How is success quantified in a restoration or management program?

This project is designed to provide baseline geologic information useful to a land manager charged with maintaining functional ecosystems and restoring those altered by human activity. The decision to focus on Black Point Drive (Figure 1) was based upon (1) logistics and (2) prompt applicability. Much of the landscape in the area is accessible from numerous improved and

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unimproved roads, making field inspection of points of interest relatively easy. In addition, the information gathered during this project could immediately be applied to an ongoing investigation of wetland management practices funded by the US Environmental Protection Agency (EPA). In due time, other quadrants could be investigated following the format developed herein.

1.1 Objectives

In order to successfully complete this project, 5 objectives were pursued:

a. (1) Review relevant literature, surveys, maps, and aerial photography, and (2) interview field scientists active in study area.

b. Establish (1) principal landscape components and (2) a practical field program capable of being completed within time allotted.

c. Conduct fieldwork on select landscape components complimented with data obtained from the (1) surface (i.e., historical photography, thematic maps) and (2) subsurface (i.e., drill logs, core borings).

d. Analyze data and construct summary documents as an initial step in understanding the geomorphology and geologic processes.

e. Test the utility of this study by applying the results to an ongoing *EPA Wetlands Initiative* currently underway within the MINWR and awarded to this NASA Summer Faculty Fellow (Randall W. Parkinson).

1.2 Operational Hypothesis

Prior to the initiation of this project, the following operational hypothesis was established:

*The principal landscape components (geomorphology) of Black Point Drive reflect interaction between surficial sediments deposited in association with late-Quaternary sea-level highstands and the evolution of late-Cenozoic sub-surface karstic formations.*

This interaction requires the presence of sub-surface limestone formations and should be most obvious in the western portion of MINWR/KSC, where the sandy late-Quaternary overburden is thinnest and where landscape features generally indicative of pervasive limestone dissolution are most apparent (Figure 1).

## 2.0 BACKGROUND

2.1 Description of Study Area

*Surface*. The geomorphology of MINWR/KSC has been previously described by Brooks (1972) and references cited therein. More recently, Clark (1987) proposed four surface aquifer terrains (Figure 1): (1) dune, (2) ridge[2] & swale, (3) western, and (4) marsh. The soils and sediments of this region have just been reviewed by Schmalzer and others (2000). The *dune* terrain is located along the

[2] As positive relief features in this terrain are no longer active aeolian dunes, Clark's (1987) label has been changed from dune & swale to ridge & swale.

eastern margin of Cape Canaveral. The terrain consists of recent, wave-dominated shorelines and aeolian dunes reaching elevations in excess of 10 m. Sediments consist of mid- to late-Holocene skeletal quartz sand; soil formation is minimal and classified as coastal by Schmalzer and others (2000). The *rigde & swale* terrain occupies most of the landscape east of the NASA Parkway. In this region, an undulatory topography is present and known to have formed as a progradational beach ridge complex during a late-Pleistocene sea-level high stand (110,000 yrbp, see Brooks 1972). Landscape elevation and local relief are diagnostic of this terrain and responsible for the presence of narrow, parallel bands of xeric, mesic, and hydric habitats. Distinct soil types also map as parallel bands corresponding to recent plant communities and generally consist of shelly quartz sand with varying amounts of organic matter (coastal, acid scrub, flatwood or hammock soils). Quartz-rich silt and clay, associated with fresh- and salt-water soils are encountered in the hydric habitats of the ridge & swale terrain.

The Black Point Drive area lies primarily in the *western* terrain, located landward of the NASA Parkway. It consists of subdued to indistinguishable beach ridges and sink hole depressions (Brooks 1972). The area now hosts flatwood, hardwood hammock and freshwater-wetland plant communities. Surface sediments consist of shelly quartz sand, locally organic rich or muddy. These correspond to flatwood, hammock or freshwater wetland soils (Schmalzer and others 2000). Thin and discontinuous coquina rock formations have also been described from this area. There is ample evidence of limestone dissolution, including the presence of a micritic cap rock, caliche crusts, and circular depressions (Figure 1). The depressions contain freshwater wetland or open water. The landward margin of MINWR/KSC consists of *marsh* terrain. Blackish-water wetlands are the principal plant community as the landscape is <1 m above sea level. Perhaps the most diagnostic feature of the marsh terrain is the presence of open water features, such as circular lakes and dissolution(?) channels. The area's surface sediment consists of shelly quartz sand and silt, locally enriched in organic matter or mud, and grouped into the saltwater wetland soil class.

*Subsurface*. Based upon the work of Brown and others (1962) and Clark (1987), the subsurface stratigraphy of MINWR/KSC is known to consist of five geologic age groups: (1) Recent, (2) Pleistocene, (3) Pliocene, (4) Miocene, and (5) Eocene (Table 1 and Figure 2). The Quaternary (Recent and Pleistocene) consist of undifferentiated marine quartz sand deposited in association with sea-level high stands and intermittently subjected to the subaerial processes of weathering and erosion. Radio-isotopic analysis (Brooks 1972) yields the following ages for prominent geologic features along a regional west to east transect: 110,000 yrbp, mainland and Atlantic Coastal Ridge; western Merritt Island, 240,000 yrbp; eastern Merritt Island, 110,000 yrbp; Banana River, 20,000 to 45,000 yrbp; Cape Canaveral, 7,000 yrbp to Recent. Black Point Drive is located in western Merritt Island and therefore upon a 240,000 year old succession of inter-bedded clastic and biogenic sediments.

Table 1. Stratigraphic units of northwest Merritt Island. After Brown and others (1962).

| Geologic Age | Stratigraphic Unit | Depth (m) | Description |
|---|---|---|---|
| Recent<br><br>Pleistocene | Pleistocene & Recent deposits | 0 - 15 | Skeletal quartz sand; locally organic-rich or coquina |
| Pliocene | Upper Miocene or Pliocene deposits | 15 - 25 | Greenish-gray, sandy fossiliferous marl |
| Miocene | Hawthorn Formation | 25 - 40 | Phosphatic greenish-gray, sandy marl or clay |

| | | | |
|---|---|---|---|
| Eocene | Ocala Group | 40 - ? | White to cream, friable and porous coquina; soft, chalky marine limestones |

The underlying Pliocene to late-Miocene consists of sandy silt, clay, and marl known locally as the confining layer because it separates the surface aquifer from the regional (Floridan) aquifer. This contact is encountered at ~15 m. These sediments were deposited upon the Hawthorn Formation, a fine-grained, phosphatic Miocene marine deposit. Eocene limestones are encountered ~40 m below sea level. Geologic cross-sections (see Figure 12 and 13 in Brown 1962) suggest the contact between Eocene and Miocene deposits is very irregular, while the overlying contacts between the younger geologic age groups are nearly horizontal.

2.2 Methods

*Surface*. This project was initiated by undertaking a survey of historical photography. Images depicting various portions of Black Point Drive were obtained for the following years: 1943, 1973, 1984, 1995, and 1999. Inspection of photography provided information on natural (i.e., landscape submergence) and anthropogenic (mining, impoundment construction) processes which were active during historical times.

A field program was then designed to catalog (1) surface sediments and soils, (2) plant communities, (3) submergent and emergent terrains, and (4) presence or absence of limestone beds exposed by natural (i.e., erosion) or anthropogenic (i.e., ditching) means. All sites were accessed using existing improved and unimproved roads.

*Subsurface*. Investigation of the subsurface geology was undertaken using: (1) remediation and groundwater monitoring well reports (i.e., Clark 1987, Universal 1998), (2) core samples (i.e., Wilson Corners Groundwater Remediation Site, provided by HSA Engineers & Scientists), (3) outcrops, and (4) literature (i.e., Brown and others1962).

## 3.0 RESULTS

3.1 Surface

The Black Point Drive area of MINWR/KSC consists of a featureless sandy surface gently dipping westward from ~3 m above sea level to ~0.5 m at the boundary with the marsh terrain. Inspection of surficial sediments indicates the presence of a shelly organic-rich quartz sand. The poor preservation of shell material (i.e., corroded, chalky) suggests this component of the sediment is actively undergoing dissolution. High organic content is a result of *in situ* production of roots and above-ground litterfall; both of which are probably contributing to acidic surface-water conditions and the chemical weathering of biogenic sediment.

Plant communities within the Black Point Drive area consist primarily of slash pine flatwood, hardwood hammock, and freshwater wetlands. Flatwood plant communities are the most extensive habitat, extending from the eastern boundary of the study area westward into hardwood hammock and freshwater wetland. Towards the marsh terrain, flatwood plant communities become increasingly isolated and occur as patches within freshwater wetlands. Inspection of a number of these patches revealed an apparent association with coquina rock at or very near (<1 m) the surface. Open water is present at a limited number of sites and is generally indicative of the presence of an inactive, shallow limestone quarry. Inspection of historical photographs suggests mining operations were activated during the construction of impoundment dikes (late 1950s and early 1960s) and after completion of unimproved roads and drainage ditches (pre-1943). All but one of the mines are located in the flatwood habitat, an observation consistent with the possible affinity of this plant community towards coquina outcrops.

Along the western margin of Black Point Drive open water is widespread and associated with topographic depressions. These too represent alterations to the natural landscape as they formed by management induced water level elevation. In areas of submergence, the surface sediment layer is often sandy and subjected to wave-induced physical reworking. Organic-matter accumulation is minimal and restricted to a basin=s low-energy embayments or Aleeward@ margins.

3.2 Subsurface

Inspection of well logs and core borings obtained from the Black Point Drive area revealed the presence of a stratigraphic succession consistent with that first published by Brown and others (1962). Late-Quaternary sediments are present in the upper ~15 m of the succession. Sedimentology, stratigraphy, and a knowledge of sea-level history suggests these marine sands were deposited during a late-Pleistocene (110,000 yrbp) sea-level highstand and subjected thereafter to subaerial processes of weathering and erosion. As the area has not yet been submerged during the most recent interval of deglaciation and concomitant sea-level rise, sediment *deposition* has been minimal. The only processes to modify the stratigraphic succession of Black Point Drive over the past 15,000 yrs are: (1) *in situ* production of organic material and (2) reduction of skeletal content through dissolution. In select (n~3) core borings obtained from the Wilsons Corner groundwater remediation site (Figure 1) a thin (<0.5 m), highly weathered (chalky) limestone layer was observed in the upper 2 m.

The effects of sub-aerial exposure are minimal below ~5 m. The preservation of marine molluscs is phenomenal at depths of 5 to 15 m. Many of the shells still retain their delicate architecture and color; they could easily be mis-identified as modern sediments if the stratigraphic context and local sea-level history were not known. Clay-rich beds of Pliocene-Miocene time are generally encountered at -15 m and these are clearly delineated from the overlying sediments by texture, composition, and color.

No recent cores have penetrated pre-Pliocene or Miocene sediments and therefore no new data were collected. Drilling to depths >15 m may compromise the integrity of the confining layer and induce contamination of the regional aquifer. All data describing these older sediments were obtained from Brown and others (1962). According to these authors, sediments deposited during Miocene and older times are present beneath the MINWR/KSC at a depth of ~25 m. The first occurrence of limestone was encountered within Eocene beds (Ocala Group) at a depth of at least 40 m (Figure 2). The limestone surface is highly irregular (c.f. Figures 12 and 13, Brown and others 1962), suggesting weathering and erosion lowered elevations significantly. The extremely high permeability of these marine limestones is indicative of karstification via groundwater dissolution. The relief of this irregular contact is not translated in the overlying beds, suggesting the karstification processes ceased prior to their deposition.

## 4.0 DISCUSSION

4.1 Relevance to Operational Hypothesis

There is abundant geomorphic evidence in the *western* and *marsh* terrains of Black Point Drive to infer limestone dissolution and the subsequent formation of a karstic landscape. This type of weathering requires a humid climate and the presence of limestone bedrock in close proximity to the surface. East central Florida is subjected to humid climatic conditions, however the first appearance of contiguous limestone formation within the stratigraphic succession of MINWR/KSC is at a depth of ~40 m. This is inconsistent with the operational hypothesis of this investigation; a karstic imprint on the landscape requires the presence of much shallower limestone beds undergoing dissolution during late-Quaternary times.

Numerous limestone outcrops are present within Black Point Drive and evidence of chemical weathering is abundant, including: micritic cap rock, caliche crust, and circular depressions. However, the coquina layers are relatively thin (<1 - 2 m) and it is difficult to envision how their dissolution could produce extensive circular or channel-like depressions with a diameter or length in excess of 1 km (Figure 1).

4.2 Management Implications

This investigation collected data applicable to understanding the paleo-environmental evolution of Black Point Drive and the surrounding area. The mainland coast, Merritt Island, and Cape Canaveral are geomorphic features that formed in association with the following late-Pleistocene sea-level highstands: (1) 240,000 yrbp, (2) 110,000 to 125,000 yrbp, (3) 20,000 to 45,000 yrbp, and (4) modern. During these times, skeletal quartz sand accumulated along at the coastline, in some cases prograding seaward as an undulatory beach ridge complex. During intervening lowstands, these deposits were subjected to chemical weathering and erosion. The presence of extensive dissolution features within ~5 m of the surface indicates weathering initially induced pervasive near-surface leaching and localized cementation at greater depths. Subsequent lowstands subjected lithified shell beds to dissolution and the formation of karstic features thereafter. These landforms are most abundant in the western region of Merritt Island, decreasing eastward towards the ridge & swale terrain. The processes responsible for the observed gradient in karstic landform distribution are unclear at present. The gradient may reflect: (1) spatial distinctions in the elevation, character or age of buried (pre-Miocene) limestone formations, (2) dissolution history of late-Quaternary coquina, and/or (3) thickness of unconsolidated surface sediment. More detailed evaluation of *subsurface* data will be necessary before this uncertainty can be resolved.

The recent acceleration in late-Holocene sea-level rise, complemented by elevated water level management strategies, has prompted the formation of extensive wetlands during historical times. In areas of higher elevation, slash pine flatwood and hardwood hammock habitats remain. If these conditions persist, the expansion of brackish-water wetlands and invasion of hydric plant communities into mesic terrains can be expected.

From a technical point of view, sedimentation within MINWR/KSC has been minimal and restricted primarily to the *in situ* production of organic matter and accumulation of surface litter. *Destructional* processes are widespread. In submerged areas, the surface layer is being reworked by wave-induced circulation. Soils beneath mesic terrains are undergoing dissolution via downward percolation of acidic surface water. Hydrologic conditions created by the most recent sea-level highstand and managed water-level elevations have probably minimized the potential effects of karstification on the area=s landscape.

The long-term (decades) prognosis of wetlands will be solely dependant upon biogenic processes. In contrast to wetland areas of the Gulf of Mexico or the more northern Atlantic coasts, fine-grained inorganic sediment is not a significant component of the sediment budget. Wetlands will persist or even expand into adjacent areas only if organic-matter production and accumulation can keep pace with rising water level. Managers must therefore work to understand the biogenic processes of sedimentation and the potential effects of water level management.

## 5.0 CONCLUDING REMARKS

The Black Point Drive area of MINWR/KSC consists of extensive flatwoods, hardwood hammock and wetland habitats that have colonized late-Quaternary skeletal quartz sands. These sediments were deposited during a preceding sea-level highstand and are currently undergoing localized physical reworking and pervasive chemical dissolution. Although there is abundant geomorphic evidence of karstification in the western portion of Merritt Island, the conditions responsible for the formation of these landforms remain enigmatic. These features may have formed via the chemical dissolution of near-surface coquina beds and/or buried Eocene limestone. The effects of Holocene sea-level rise and water-level management have probably reduced the potential for continued karstification and expanded the distribution of brackish- and fresh-water wetlands. The long-term prognosis of wetland persistence will be dependent solely upon the rate of biogenic sediment production and accumulation relative to the change in water-level elevation induced by natural and anthropogenic factors. Therefore, land managers must consider the effects of current water management strategies on organic-matter production and accumulation if wetland protection is one of their mandates.

## 6.0 ACKNOWLEDGMENTS

The following scientists are acknowledged for their assistance: Melissa Hensley, Ross Hinkle, Mark Provancha, and Paul Schmalzer. Support was also provided by my NASA Colleague, Kelly Gorman. Inspection of subsurface data was made possible by Jim Hayman and Darcie McGee (HSA Engineers & Scientists). Access to field sites and permitting was granted by the US Fish and Wildlife Service and in particular Gary Popotnik and Mark Epstien. Ron Brockmeyer, St. Johns River Water Management District, is acknowledged for his support.

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## Appendix 5: Establishing a Geologic Baseline of Cape Canaveral's Natural Landscape: Black Point Drive

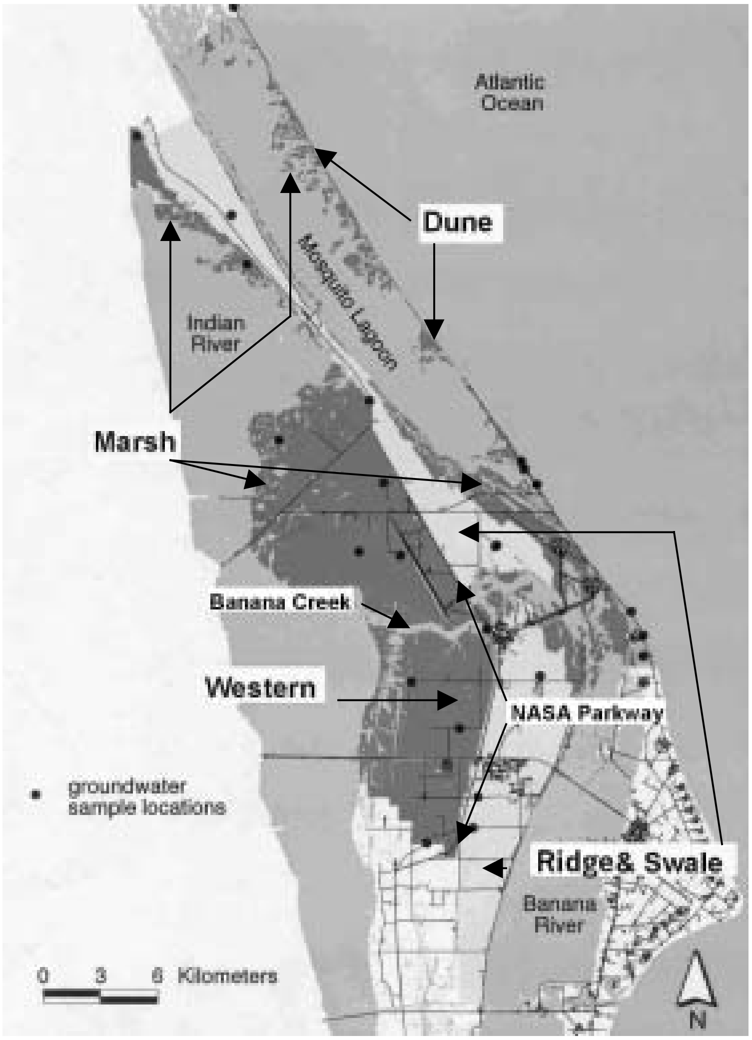
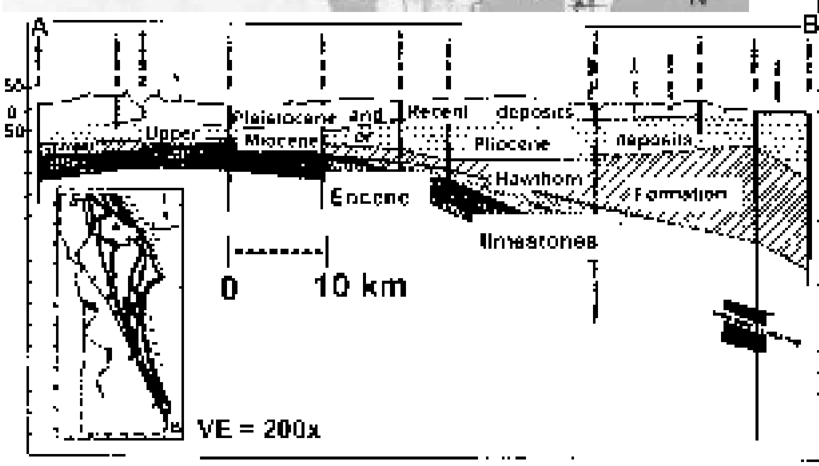



**Figure 1.** Cape Canaveral's principal geomorphic terrains: (1) dune, (2) ridge & swale, (3) western, and (4) marsh (after Clark 1987). Black Point Drive located north of Banana Creek and west of NASA Parkway. Wilson Corners located across road at north end of landing strip.

**Figure 2 (below).** Cross-section of coastal stratigraphy in Brevard County, Florida, constructed using wells shown in inset. Asterisks (*) denote Black Point Drive. Vertical scale in ft (50 ft ~ 15 m). After Brown and others (1962).



## Appendix 6: Coastal National Park Units

**Coastal NPS Units:**

| | | |
|---|---|---|
| 10 | Alaska | (8 Gulf of Alaska; 2 Bering Sea) |
| 18 | Northeast | (18 Atlantic) |
| 25 | Southeast | (14 Atlantic; 11 Gulf of Mexico) |
| 9 | Intermountain | (1 Gulf of Mexico; 8 reservoir/lakeshore) |
| 28 | Pacific West | (12 Pacific Coast; 10 Pacific Islands; 6 reservoir/lakeshore) |
| 7 | Midwest | (7 Great Lakes) |
| 97 | TOTAL | (76 marine; 21 lakeshores) |

Alaska (10)

Aniakchak NMP
Bering Land Bridge NP
Cape Krusenstern NM
Glacier Bay NPP
Katmai NPP
Kenai Fjords NP
Klondike Gold Rush NHP
Lake Clark NPP
Sitka NHP
Wrangell-St. Elias NPP

North Atlantic (18)

Acadia NP, ME
Assateague Island NS, MD/VA
Boston Harbor Islands NRA, MA
Boston NHP, MA
Cape Cod NS, MA
Castle Clinton NM, NY
Colonial NHP (Jamestown, Cape Henry), VA
Fire Island NS, NY
Fort McHenry NMHS, MD
Gateway NRA, NY/NJ
George Washington Birthplace NM, VA
Governor's Island NM, NY
New Bedford Whaling NHP, MA
Sagamore Hill NHS, NY
Saint Croix Island IHS, ME
Salem Maritime NHS, MA
Statue of Liberty NM, NY/NJ
Thomas Stone NHS, MD

Southeast Atlantic (14)

Biscayne NP, FL
Canaveral NS, FL
Cape Hatteras NS, NC
Cape Lookout NS, NC
Castillo de San Marcos NM, FL
Cumberland Island NS, GA
Fort Caroline NM, FL
Fort Frederica NM, GA

## Appendix 6: Coastal National Park Units

Fort Matanzas NM, FL
Fort Pulaski NM, GA
Fort Raleigh NHS, NC
Fort Sumter NM, SC
Timucuan EHP, FL
Wright Brothers NM, NC

Gulf of Mexico (12)
Big Cypress NP, FL
Buck Island Reef NM, VI
De Soto NM, FL
Dry Tortugas NP, FL
Everglades NP, FL
Gulf Islands NS, FL/MS
Jean Lafitte NHPP, LA
Padre Island NS, TX
Salt River Bay NHP&EP, VI
San Juan NHS, PR
The Virgin Islands Coral Reef NM, VI
Virgin Islands NP, VI

Pacific Coast (12)
Cabrillo NM, CA
Channel Islands NP, CA
Ebey's Landing NHR, WA
Fort Clatsop NM, OR
Fort Point NHS, CA
Golden Gate NRA (Presidio, Alcatraz), CA
Olympic NP, WA
Point Reyes NS, CA
Redwood NP, CA
San Francisco Maritime NHP, CA
San Juan Island NHP, WA
Santa Monica Mountains NRA, CA

Pacific Islands (10)
Haleakala NP, HI
Hawaii Volcanoes NP, HI
Kalaupapa NHP, HI
Kaloko-Honokohau NHP, HI
NP of American Samoa, AS
Pu'uhonua O Honaunau NHP, HI
Pu'ukohola Heiau NHS, HI
War in the Pacific NHP, GU
USS *Arizona* Memorial, HI

Great Lakes (7)
Apostle Islands NL, WI
Indiana Dunes NL, IN
Isle Royale NP, MI
Perry's Victory and IPM, OH

Pictured Rocks NL, MI
Sleeping Bear Dunes NL, MI
Voyageurs NP, MN

**Reservoirs/ Large Lakes (14)**

Amistad NRA, TX
Bighorn Canyon NRA, MT/WY
Chickasaw NRA, OK
Crater Lake NP, OR
Curecanti NRA, CO
Glen Canyon NRA, UT
Lake Chelan NRA, WA
Lake Mead NRA, AZ/NV
Lake Meridith NRA, TX
Lake Roosevelt NRA, WA
Ross Lake NRA, WA
Whiskeytown NRA, CA
Yellowstone NP, WY/MT/ID
Yosemite NP, CA

For updates or additional information please contact:

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For more information on specific parks:

http://www.nps.gov/parks.html

(NPS Update – 10/16/01 by R. Beavers)

## Appendix 7: Status of NSP Coastal and Lakeshore Areas for Geologic Resources Inventory (GRI) as of September 25, 2002

| PARK NAME | State | Park Type 3 | Scoping Meeting 4 | Digital Mapping Status | Summary |
|---|---|---|---|---|---|
| Acadia NP | ME | C | no | preliminary | Maine GS published both bedrock and surficial maps at 50,000 scale in late 1980's; Karen Anderson at ACAD has digital files for each coverage. Needs reviewed for conformity with GRI model |
| Amistad NRA | TX | L | no | inactive | No information available. |
| Aniakchak NM | AK | C | no | preliminary | Surficial geology by USGS for Ugashik quad in MrSid format; projected to Alaska Albers projection. |
| Apostle Islands NL | WI | L | no | inactive | digital files for quarries and sand spits only |
| Assateague Island NS | MD | C | no | inactive | No information available |
| Bering Land Bridge Npres | AK | C | no | inactive | Know Patricia Heiser doing some mapping here |
| Big Cypress Npres | FL | C | no | inactive | No information available. |
| Bighorn Canyon NRA | MT | L | no | inactive | MT GS has worked with BICA staff to produce waysides on park's geology; files available from GRI. Contain good write-ups of stratigraphy and geologic processes in the park. |
| Biscayne NP | FL | C | no | inactive | No information available. |
| Boston Harbor Islands NRA | MA | C | no | preliminary | http://www.nps.gov/gis/park_gisdata/massachusetts/boha.htm has surficial geology metadata and other information |
| Buck Island Reef NM | VI | C | no | inactive | No information available. |
| Cabrillo NM | CA | C | no | inactive | No information available. |
| Canaveral NS | FL | C | no | inactive | No information available. |
| Cape Cod NS | MA | C | no | inactive | USGS has website for their activities here; need more details from them; http://woodshole.er.usgs.gov/epubs/oldale_geolcc/32index.html |
| Cape Hatteras NS | NC | C | Yes 04-03-00 | planned | NC GS, USGS, ECU cooperative funded to produce geomorphic landform maps of CAHA, CALO, FORA, WRBR areas; Should try to contact Dare County, NC about digital FEMA maps for the area as well |
| Cape Krusenstern NM | AK | C | no | inactive | No information available. |
| Cape Lookout NS | NC | C | Yes 04-03-00 | planned | NC GS, USGS, ECU cooperative funded to produce geomorphic landform maps of CAHA, CALO, FORA, WRBR areas; Should try to contact Dare County, NC about digital FEMA maps for the area as well |
| Castillo de San Marcos NM | FL | C | no | inactive | No information available. |
| Channel Islands NP | CA | C | no | preliminary | http://www.nps.gov/gis/park_gisdata/california/chis.htm; lots of coastline stuff and geology for Santa Rosa Island |
| Chickasaw NRA | OK | L | no | inactive | No information available |
| Colonial NHP | VA | C | no | preliminary | needs reviewed for conformity to GRI model. Has geologic coverage at small scale (250,000); probably need larger scale maps for park resource management needs |
| Crater Lake NP | OR | L | no | in-progress | GRI staff will work with USGS in FY-2001 on project completion |
| Cumberland Island NS | GA | C | no | inactive | No information available |
| Curecanti NRA | CO | L | Yes 08-26-98 | complete | available for download from: http://www3.nature.nps.gov/im/gis/ftp/ftparchive.cfm |
| Dry Tortugas NP | FL | C | no | inactive | http://www.nps.gov/gis/park_gisdata/florida/drto.htm; but shorelines and bathymetry data |
| Ebey's Landing NH Reserve | WA | C | Yes 09-12-02 | inactive | WA DNR has digital coverage of entire state digital at 100,000 scale; needs converted to GRI model |
| Everglades NP | FL | C | no | inactive | http://www.nps.gov/gis/park_gisdata/florida/ever.htm; but only coastlines |
| Fire Island NS | NY | C | no | inactive | No information available |

3 Type is "C" for coastal parks with tidal influence; “L" is for lakeshore parks.
4 Scoping Meeting Status and if applicable, date performed.

## Appendix 7: Status of NSP Coastal and Lakeshore Areas for Geologic Resources Inventory (GRI) as of September 25, 2002

| PARK NAME | State | Park Type 3 | Scoping Meeting 4 | Digital Mapping Status | Summary |
|---|---|---|---|---|---|
| Fort Caroline NMem | FL | C | no | inactive | No information available. |
| Fort Clatsop NMem | OR | C | no | inactive | No information available. |
| Fort Frederica NM | GA | C | no | inactive | No information available. |
| Fort Matanzas NM | FL | C | no | inactive | No information available. |
| Fort Point NHS | CA | C | no | inactive | No information available. |
| Fort Pulaski NM | GA | C | no | inactive | No information available. |
| Fort Sumter NM | SC | C | no | inactive | need specifics from SC GS (Bill Clendenin) |
| Gateway NRA | NY | C | no | inactive | No information available. |
| George Washington Birthplace NM | VA | C | no | planned | No information available |
| Glacier Bay NP | AK | C | no | preliminary | USGS has done significant mapping; apparently AKSO has digital geology from Dave Brew (USGS); check with Sara Wesser on this |
| Glen Canyon NRA | UT | L | Yes 09-23-99 | in-progress | awaiting digital geology from UT GS; need report synthesized from UGA guidebook #28 |
| Golden Gate NRA | CA | C | no | inactive | No information available. |
| Gulf Islands NS | FL MS | C | no | inactive | No information available. |
| Haleakala NP | HI | C | no | inactive | http://volcanoes.usgs.gov/ |
| Hawaii Volcanoes NP | HI | C | no | planned | USGS has I-2685 (Maps showing development of the Pu'u 'O'o-Kupaianaha Flow Field); not known if it's digital though; also consult http://volcanoes.usgs.gov/ |
| Indiana Dunes NL | IN | L | no | inactive | http://www.nps.gov/gis/park_gisdata/indiana/indu.htm ; some landform cover stuff |
| Isle Royale NP | MI | L | no | preliminary | NPS clearinghouse has files that need reviewed for conformity with GRI model |
| Jean Lafitte NHP & PRES | LA | C | no | inactive | No information available. |
| Kalaupapa NHP | HI | C | no | inactive | http://volcanoes.usgs.gov/ |
| Kaloko-Honokohau NHP | HI | C | no | inactive | coastline data exists digitally; also http://volcanoes.usgs.gov/ |
| Katmai NP | AK | C | no | preliminary | http://www.nps.gov/akso/gis/katm/katm_ptp.htm ; some for earthquake displacement… 3/1/02 also for Mt. Katmai - downloaded to z drive, gis, preliminary, alaska, katm |
| Kenai Fjords NP | AK | C | no | preliminary | GRI staff have obtained digital geologic coverage from NPS clearinghouse; need to review for conformity with GRI model. |
| Klondike Gold Rush NHP | AK | C | no | inactive | No information available. |
| Lake Clark NP | AK | C | no | planned | GRI staff have obtained digital geologic coverage from NPS clearinghouse; need to review for conformity with GRI model. GRI staff will work on in FY-2001 |
| Lake Mead NRA | NV | L | Yes 02-12-02 | in-progress | USGS working on (2) 100,000 sheets that will cover most of park; need maps for southern portion though. Sue Beard has data at USGS in Flagstaff |
| Lake Meredith NRA | TX | L | no | inactive | park has submitted TA requests to GRD to assist them with producing a digital geologic map for both ALFL and LAMR; no action taken on GRI half yet |
| Lake Roosevelt NRA | WA | L | Yes 09-10-02 | planned | LARO wants numerous surficial maps digitized for park management needs mapped by BOR; GRI staff wish to obtain maps from LARO to register and rectify, and will digitize in FY-2003 |
| National Park of American Samoa | HI | C | no | inactive | http//www.nps.gov/gis/park_gisdata/americansamoa/npsa.htm; has coastline and coral reefs; also NPSA GIS supplied GRI staff with TIF files of 1981 Coastal Atlas for American Samoa; could be georeferenced and digitized |
| Olympic NP | WA | C | Yes 09-12-02 | preliminary | know of published USGS map I-994 at 1:125k; it's also digital but needs to be reviewed for GRI conformity |

# Appendix 7: Status of NSP Coastal and Lakeshore Areas for Geologic Resources Inventory (GRI) as of September 25, 2002

| PARK NAME | State | Park Type 3 | Scoping Meeting 4 | Digital Mapping Status | Summary |
|---|---|---|---|---|---|
| Padre Island NS | TX | C | no | inactive | "Padre Island NS: A guide to the Geology, natural environments, and history of a Texas barrier island" is available; contains a paper map. Unknown if it is digital. |
| Pictured Rocks NL | MI | L | no | inactive | know of work by William Blewett; have specific publications. Not known if digital |
| Point Reyes NS | CA | C | no | preliminary | http://wrgis.wr.usgs.gov/open-file/of97-456/ |
| Pu'uhonua o Honaunau NHP | HI | C | no | inactive | No information available. |
| Puukohola Heiau NHS | HI | C | no | inactive | No information available. |
| Redwood NP | CA | C | no | preliminary | Needs reviewed for conformity to GRI model. |
| Sagamore Hill NHS | NY | C | no | inactive | No information available. |
| San Juan Island NHP | WA | C | Yes 09-12-02 | inactive | No information available. |
| Santa Monica Mountains NRA | CA | C | no | inactive | Doug Morton of USGS doing work here ; need more details |
| Sitka NHP | AK | C | no | inactive | No information available. |
| Sleeping Bear Dunes NL | MI | L | no | inactive | work with USGS Bruce Jaffe for details of his work there |
| Thomas Stone NHS | MD | C | no | inactive | No information available. |
| Timucuan Ecological & Hist Preserve | FL | C | no | inactive | No information available. |
| Virgin Islands NP | VI | C | no | preliminary | USGS mapped area; needs digitized though |
| Voyageurs NP | MN | L | Yes 06-01-00 | In-progress | have obtained 24k all quads from MN GS and have converted to GRI model; awaiting help file completion and will upload to http://www3.nature.nps.gov/im/gis/ftp/ftparchive.cfm ASAP |
| War in the Pacific NHP | GU | C | no | inactive | No information available. |
| Whiskeytown-Shasta-Trinity NRA | CA | L | no | planned | USGS has several projects occurring; need to acquire digital geology from them |
| Wrangell-St Elias NP | AK | C | no | preliminary | GRI staff have obtained digital geologic coverage from NPS clearinghouse; need to review for conformity with GRI model. |
| Yellowstone NP | WY | L | no | preliminary | Good project for Anne Poole; GRI staff have obtained digital geologic coverage from NPS Clearinghouse; need to review for conformity with GRI model. USGS has also published OF |
| Yosemite NP | CA | L | Yes 09-25-02 | inactive | No information available. |

## Appendix 8: Geologic Resources Inventory Tasks Related to Coastal Landform Mapping

As a result of the Coastal mapping Protocols Workshop for Atlantic and Gulf National Parks that is summarized in this report, GRI staff drafted initial lists of overall inventory action items and more specific project tasks to begin work on in FY2003. The bulleted lists will be planned in more detail and documented by GRI staff and cooperators.

### GRI Coastal Landform Mapping (CLM) Action Items

- Develop and document base CLM data model/legend (from FL Workshop Report)
- Identify data sources and outline/document protocols for interpreting imagery/data into map themes
- Determine FY 2003 pilot projects and park project priorities
- Scope pilot parks if needed
- Begin base data acquisition, processing, and archiving
- Plan and initiate project(s) for imagery/data interpretation (coop./contract/in house)
- Plan and initiate field check/review and QA/QC of map(s)
- Complete development and documentation of inventory products
    - ✓ Digital map(s) with metadata, legends, theme lists, sections, help files, etc.
    - ✓ Updated GRBib
    - ✓ GRI Report with annotated list of other coastal map/data needs and research projects

### GRI Coastal Landform Mapping Project Tasks

- Acquire base data
    - Recent aerial photography and/or high resolution satellite imagery
    - High resolution elevation data (e.g., LIDAR)
    - National Wetlands Inventory
    - Topography and Bathymetry
    - Available soil and vegetation data
- Base data processing and archiving
    - Process/convert/rectify data as necessary to same GIS format and datum/projection
    - Distribute data to cooperators and archive with I&M Program
- Imagery/Data Interpretation
    - Develop/customize data attributes/legend and include in NPS Geology-GIS Data Model
    - Interpret and digitize thematic CLM polygons and associated data
- Field check/review and QA/QC CLM map
    - Validate theme polygons and correct map units as needed
    - Complete formal QA/QC of map units as may be required
- Develop and complete CLM products
    - Attribute and QA/QC digital map per NPS Geology-GIS Data Model
    - Complete fully FGDC- and GRI-compliant metadata file(s)
    - Document project tasks and write detailed unit descriptions and map summary/notes
    - Develop theme list(s), GIS map legend(s), Help file(s), and report illustrations
    - Complete GRI Report
    - Update GRBib with citations from mapping and report projects.